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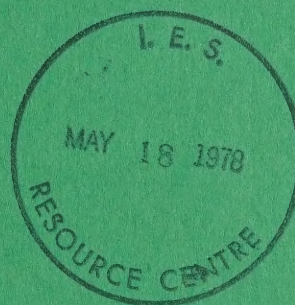
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Technical, Economic and Environmental Aspects of Wet and Dry Debarking



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Report EPS 3-WP-78-3

Water Pollution Control Directorate
March 1978

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TECHNICAL, ECONOMIC AND ENVIRONMENTAL
ASPECTS OF WET AND DRY DEBARKING

by

Beak Consultants Limited

for the

Water Pollution Control Directorate
Environmental Protection Service
Fisheries and Environment Canada

Report No. EPS 3-WP-78-3
March 1978

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ABSTRACT

Installations in eastern and western North America using hydraulic jet, mechanical ring, wet drum and dry drum debarking have been reviewed. These systems provided a representative selection and included plants using only wet or dry debarking, both wet and dry together, and dry debarking operations which had converted from wet processes. Saw mills and pulp mills processing both soft and hardwood have been considered.

Based on information from operating mills, literature and equipment suppliers, energy requirements for debarking and bark handling, as well as energy recovery from bark burning were determined. A literature survey and mill data were used to assess the effects of debarking systems on hog, chip, pulp and wood product quality. A sampling and analysis program was also initiated at selected plants to provide comparisons of residual bark levels, wood loss, salt content of chips and hog fuel, and dirt and moisture content of hog fuel for various debarking systems.

Operating costs were assessed by reviewing mill records. Capital costs and conversion requirements were also evaluated from mill and supplier information, and various other sources.

Information regarding debarking effluent characterization and treatment, and regulatory requirements has also been included.

RÉSUMÉ

La présente étude porte sur les installations de l'est et de l'ouest de l'Amérique du Nord, équipées de diverses écorceuses hydrauliques; à rotor annulaire, à tambour rotatif, fonctionnement par voie humide ou sèche. Outre qu'elle est représentative, cette sélection comprend des usines procédant à l'écorçage soit à sec, soit humide, aux deux à la fois, et certaines qui ont abandonné le procédé humide pour le sec. Il a aussi été tenu compte des scieries et des fabriques de pâtes qui s'approvisionnent à la fois conifères et de feuillus.

A l'aide des renseignements tirés des fabriques en exploitation, des publications et des fournisseurs d'équipement, on a déterminé les besoins énergétiques de l'écorçage et de la manutention de l'écorce de même que la quantité d'énergie récupérée par la combustion de l'écorce. A partir d'une étude bibliographiques et de données des fabriques, on a évalué dans quelle mesure les méthodes d'écorçage influaient sur la qualité des produits du bois, de la pâte, de copeaux et des produits du broyage. Un programme d'échantillonnage et d'analyse a aussi été entrepris dans certaines fabriques afin d'établir le pourcentage d'écorce résiduel, la perte de bois, le degré de salinité des copeaux et des déchets de bois et la teneur en eau et en saletés des déchets de bois que l'on obtient selon la méthode d'écorçage employée.

Les frais d'exploitation ont été calculés après l'étude du bilan des fabriques. Les informations fournies par les fabricants, les fournisseurs et autres ont servi à déterminer les coûts d'investissement et de la conversion.

L'étude renferme aussi des informations sur les propriétés et le traitement des effluents de l'écorçage ainsi que sur la réglementation qui s'y rattache.

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SUMMARY AND CONCLUSIONS

Bark removal is required because of the negative effects of bark on pulping processes and product quality. Sulphite pulping demands low bark residuals in its furnish while kraft pulping is able to tolerate higher levels. While there are site specific variations, wet methods of bark removal generally have the advantage of being able to achieve more complete bark removal with less wood loss and less dirt and grit in the bark and chip system. However, they have the disadvantage of producing an effluent which requires treatment, and a wet bark with a lower fuel value. The principle methods of wet debarking include hydraulic and wet drum, while their dry counterparts are the mechanical ring and dry drum.

The major variables influencing the efficiency of wet and dry debarking are the wood species, the harvesting and debarking seasons, log quality and storage methods. Generally, winter cut wood is harder to debark than summer cut wood; hardwoods have a stronger bark-to-wood bond than softwoods; irregular pulp logs can present difficulties with mechanical debarkers; and storage methods can influence the quantity, ease of removal and dirt content of the bark.

The primary reason that mills have converted from wet to dry debarking is the projected costs of effluent control. For sawmills, debarker wastewaters are the major effluent source, and for pulp mills conversion represents a significant reduction in mill effluent load.

The decision to convert from wet to dry debarking is also influenced by a need for greater energy recovery from hog fuel, especially at pulp mills. In many cases, bark pressing is a bottleneck and constant maintenance problem. Converting to dry debarking eliminates bark pressing and results in drier bark and, therefore, a potential for greater hog fuel utilization.

At pulp mill installations no difference is apparent between the moisture content of pressed hog fuel from wet debarking and that from dry debarking without pressing. However, with dry stored logs, the moisture content of hog fuel from dry debarking can be expected to be slightly lower. For sawmill installations, hog fuel moisture is less sensitive to debarking since a large proportion of hog fuel consists of sawdust and wood shavings.

Estimates were made of the economic consequences of converting from wet to dry debarking. In converting from wet to dry drum debarking, savings roughly balance additional costs. In converting from hydraulic to mechanical debarking, a net saving of $\$0.35/\text{m}^3$ is estimated.

Operating costs, which include operating labour, power and maintenance for mechanical debarking, averaged $\$0.27/\text{m}^3$ compared to $\$0.51/\text{m}^3$ for hydraulic debarking and $\$0.95/\text{m}^3$ for wet and dry drum debarking. The lower cost for mechanical compared to hydraulic debarking can be attributed to lower power and maintenance costs, while the higher cost for drum debarking is mainly due to greater manpower requirements.

Mechanical debarking installations have an average power requirement of $1.2 \text{ kWh}/\text{m}^3$. Hydraulic, and wet and dry drum installations exhibit a similar demand for power, in the range of 7.7 to $8.1 \text{ kWh}/\text{m}^3$, which is several times the requirement for mechanical debarking.

Capital costs were estimated for wet and dry debarking systems which included debarkers and associated equipment but not effluent treatment facilities. Costs for a dry drum system were estimated to be approximately the same as for a wet drum system, while a mechanical ring debarking system was estimated to be substantially less than a hydraulic system.

Pulp mills contacted in this study experienced higher bark residuals in their chips or reduced debarking rates after converting from wet to dry drum debarking. At kraft mill installations, bark residuals after conversion were 1 to 3% which is two to three times those previously encountered. While these levels were acceptable at these particular mills with regard to product quality, mills which have a limited recovery system or pulp cleaning capacity would be expected to encounter additional costs with higher bark residuals. Sulphite mills with both wet and dry debarking systems were able to achieve desired residual bark levels (less than 0.5%) with hydraulic debarking but experienced difficulty with mechanically debarked logs.

Product quality assessment for this study was based on sampling debarking installations at pulp mills and sawmills. Hydraulically and mechanically debarked sawmill logs exhibited similar levels of residual bark. With poorer quality pulp mill logs, hydraulic debarking was

superior. Bark residuals for drum debarked softwood chips were variable and, therefore, inconclusive; however, wet drum debarking of hardwood was superior to dry, producing lower levels of residual bark.

With regard to wood loss, statistically significant differences were not detected between different debarking systems; however, on the basis of average values a wood loss of 1 to 2% can be expected with hydraulic debarking, 2 to 3% with mechanical debarking, and 4 to 5% with both wet and dry drum debarking. There is little agreement of wood loss values reported in the literature, with estimates ranging from 0.1 to 10%.

Another quality consideration when dry debarking is the higher level of dirt and grit, and for coastal installations, salt in the chips and hog fuel which can govern their acceptability and marketability. For coastal installations with salt water stored logs, the salt content of the chips ranged from 0.33 to 0.96%. The bark particulate content from logs that had been debarked and stored by wet and dry methods ranged from 0.04 to 2.5%. Limited data indicate that the bark particulate content from dry debarking can be an order of magnitude higher than that from wet debarking.

The characteristics of hydraulic and wet drum debarker effluents are variable depending on many factors including wood species, climate, and log handling techniques. The most important potential pollutants in wet debarker effluent are total suspended solids, BOD_5 , toxicity, pH, and colour.

State-of-the-art effluent treatment for wet debarkers is primarily concerned with suspended solids removal; for hydraulic debarkers this treatment usually consists of screening and sedimentation, and for wet drum debarkers various combinations of screens, centrifugal separators, water extractors, and sometimes sedimentation. Existing treatment schemes vary considerably because of the differences in effluent characteristics from mill to mill.

For many wet debarkers to meet present and probable future effluent regulations, improved treatment techniques will be required. For a debarking installation with no effluent treatment except coarse screening, the annual operation and capital costs for facilities to achieve the required effluent quality could be about \$0.25/m³ of wood processed.

RECOMMENDATIONS

1. Most studies on the effects of bark residuals in chips pertain to high levels of bark; further work is required to better define the effects of lower bark residuals.
2. Mills with wet debarking systems should establish and maintain records of product quality and debarking operating costs. This information will form a basis for comparison to dry debarking in the event that conversion is considered.
3. As hog fuel is becoming a more important commodity, methods should be adopted to improve quality and standardize testing methodology. Dry storage of logs and methods of dirt removal should be investigated, particularly for dry debarking installations.
4. Wet debarker installations that are or may be faced with the installation of effluent treatment facilities should consider converting to dry debarking; the comparison should include an estimate of potential future treatment costs.
5. Wet debarker installations should establish appropriate effluent monitoring facilities including flow recorders and samplers so that the existing effluent characteristics and their variability are documented. This information, as well as adequate laboratory and pilot plant testing, will be necessary in the selection of appropriate treatment facilities.
6. Mills should investigate and, where practicable, implement methods of reducing water usage and increasing effluent recycle so that future treatment facilities will be smaller and, therefore, less costly.
7. Further pilot scale work should be performed on different debarker effluents to verify the application of equipment such as the Rotostrainer, microstrainer, and chemically-assisted clarifiers for the reduction of suspended solids.

1. INTRODUCTION

1.1 Objective

- Compare wet and dry methods of debarking logs in terms of energy requirements, economics, product quality and the effect on subsequent manufacturing processes; and
- Determine effluent characteristics, and discuss and evaluate treatment alternatives for wet debarker wastewaters.

1.2 Scope

- Describe pertinent debarking methods.
- Analyze process variables affecting the efficiency of wet and dry debarking.
- Compare the energy requirements and costs of wet and dry debarking.
- Review the effects of wet and dry debarking on product quality for the pulp and paper and wood product categories.
- Review the effects of debarking on hog fuel quality and energy recovery.
- Review the variables affecting effluent quality.
- Determine the characteristics of wet debarker effluents.
- Discuss equipment and methods used for the treatment of debarker effluents.
- Describe effective effluent treatment systems.
- Develop costs for treatment techniques.

1.3 Approach

Installations in eastern and western North America which use hydraulic jet, mechanical ring, wet drum and dry drum debarking were reviewed. These systems provided a representative selection which included installations that had operated only in a wet or dry mode; had both wet and dry operating together; or had converted from wet to dry debarking. These installations included both sawmills and pulp mills, processing both softwood and hardwood.

Based on information from operating mills, literature and suppliers, energy requirements for debarking and bark handling as well as energy recovery from bark burning were determined.

Based on information in the literature and mill data the effects of debarking on hog, chip, pulp and wood product quality were assessed. A sampling and analysis program was initiated at selected installations to provide comparisons of residual bark levels, wood loss, salt content of chips and hog fuel, and dirt and moisture content of hog fuel for various debarking systems.

Operating costs were assessed by reviewing mill records. Capital costs and conversion requirements were also evaluated from mill and supplier information, and various other sources.

A computer-assisted literature search was carried out to identify work performed in the characterization of debarker effluents and their treatment techniques. Pertinent equipment suppliers were contacted for information concerning equipment installations, performance, and costs. Government agencies were approached to acquire information regarding debarker effluent characterization and treatment, and regulatory requirements. Several mills were also contacted, and some visited, to obtain first-hand information.

2. DISCUSSION OF DEBARKING

2.1 Reasons for Bark Removal

The primary objection to bark in pulp and paper making is one of quality, manifesting itself in the form of off-colour specs in the final product. Components of bark, such as stone cells and dirt carried over with bark materials, are also objectionable. Bark has a low cellulose content, 20% or less, compared to about 50% for wood, and for a mill limited in pulping capacity the adverse effects of bark on pulp yield are significant. Other objections are bark's negative effects on the pulping process itself, including cooking chemical consumption, increases in bleach chemical requirements, and added black liquor solids loading.

For these reasons pulp mills, and sawmills supplying chips to pulp mills, practice some form of debarking and strive to keep the residual bark content of their wood chips within certain tolerances. While all pulp and paper mills incorporate systems for removal of residual dirt, these can be inefficient for removal of bark from fibre, or they can be very elaborate and expensive to do the job properly.

The amount of bark tolerated in the chips varies appreciably within segments of the industry and between individual mills depending on end use and marketing demands. High quality sulphite pulps and unbleached groundwood pulps are particularly sensitive to bark contamination; kraft pulps are more tolerant and semi-chemical pulps intended for corrugating and particle board are the most tolerant. Keays and Hatton (1974) list a tolerance level for newsprint of 1% or less and for sulphite pulp a tolerance level of below 1% and preferably less than 0.5%.

The bark tolerances of mills contacted in this study generally confirm these requirements. Kraft mills specified residual bark standards which ranged from 0.2% to no standards at all. An eastern newsprint mill strived to maintain 0.2% bark, while three western sulphite mills specified bark contamination to be less than 0.5%. Sulphite mills were concerned about the effects of inner bark on bleach chemical consumption and viscose filtration. Data obtained from ITT Rayonier indicated that inner bark exerts seven times the normal chlorine demand and twice the normal caustic demand and appreciably affects viscose filtration, as

illustrated in Figure 1. The general opinion from mills with semi-chemical production was that bark is undesirable in corrugating medium manufacture but can be tolerated (Branch, 1971; Keays and Hatton, 1974).

A more detailed analysis has been made of the effects of bark on kraft pulp because it constitutes over 80% of Canadian market pulp, and over 90% of world chemical pulp production. With regard to pulp properties, Horn and Auchter (1972) concluded that the strength of bleached and unbleached pulps was not affected by the presence of bark. Keays and Hatton (1974), in reviewing available data, reached the same conclusions. A more recent study (PPRIC, 1976) indicated that effects were variable depending on wood species. In the pulping of chips with 15% bark, burst strengths decreased by 5 to 10% and tear strengths ranged from a 10% decrease to an increase of 16% compared to pulp with zero bark content.

Several authors have investigated the effects of bark in bleached kraft pulp production and its economic consequence. Most of these data pertain to the effects of the inclusion of large quantities of bark (3 to 10%). Thus, projection of these effects to the lower quantities of bark usually encountered after debarking (0.5 to 3%) can only be regarded as estimates. Thomas and Howse (1975) point out that the economic consequences of bark in kraft pulping depend on the type of bark, production bottlenecks, its value as a fuel, the pulp end use and possible undefined problems such as filter drainage.

Both Thomas and Howse (1975) and Keays and Hatton (1974) demonstrated how the economic consequences are dependent upon whether the mill is limited in digester and recovery boiler capacity. Bark reduced the net pulp yield on wood, and due to increased alkali requirements and organic solids, a greater solids load is placed on the recovery system. Thus, a mill limited in digester and recovery capacity will encounter reduced output. If a mill is not limited in digester and recovery capacity, credit must be given to the fibre yield from bark and additional heat recovered. Wawer (1975), reporting on mill trials investigating the inclusion of whole tree chips in the furnish, found a substantial yield reduction due to bark, because of over-cooking. Wawer stressed the need for individual mills to define their tolerance for bark.

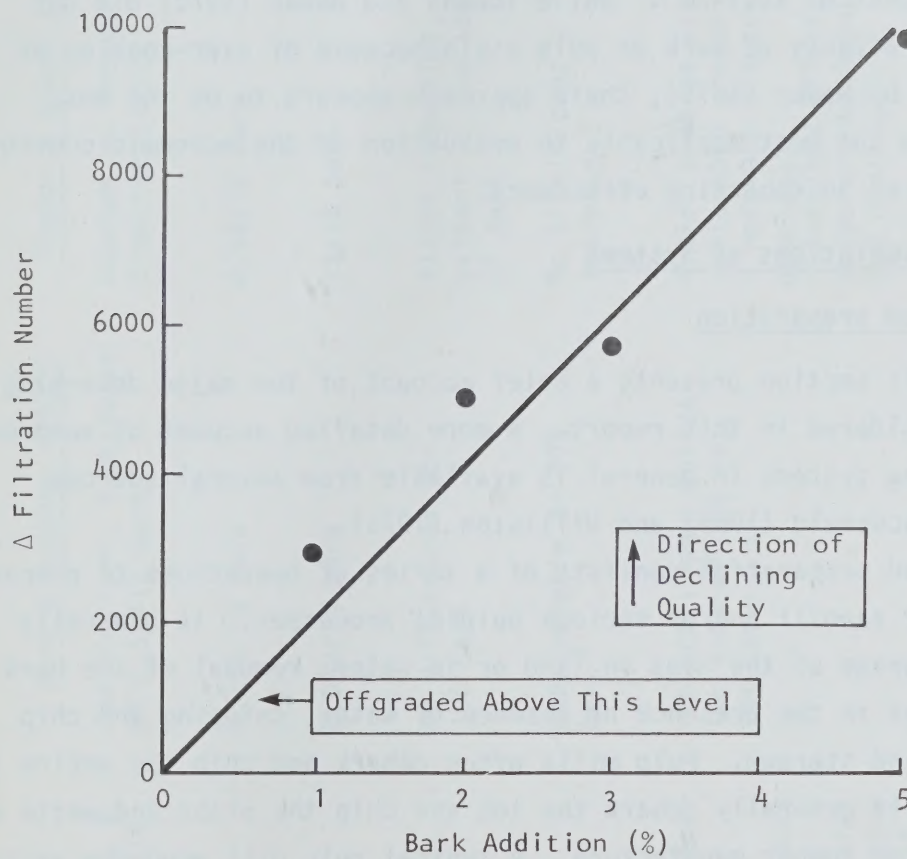


FIGURE 1. INFLUENCE OF BLEACHED HEMLOCK INNER BARK ON VISCOSE FILTRATION
(Courtesy of ITT Rayonier Inc.)

Table 1 summarizes from various sources the effects of bark on pulp quality and other process parameters. Comparison reveals that effects noted can vary appreciably. As a result, estimates of the economic consequences of bark cover a broad range of values. The difficulty of accurately assessing some of the effects quoted is also apparent. Costs, or savings, due to the inclusion of bark are summarized in Table 2 and should be regarded as approximate estimates only. The bulk of the additional costs or savings quoted are due to yield effects. Values quoted range from a savings of \$0.07/m³ of wood processed to an additional cost of \$0.94/m³. While Thomas and Howse (1975) did not discuss the effects of bark on pulp yield because of over-cooking as pointed out by Wawer (1975), their approach appears to be the most rational and the most applicable to evaluation of the economic consequences of differences in debarking efficiency.

2.2 Descriptions of Systems

2.2.1 Wood preparation

This section presents a brief account of the major debarking systems considered in this report. A more detailed account of woodroom and debarking systems in general is available from several sources including Macdonald (1969) and Williston (1976).

Wood preparation consists of a series of operations to prepare the wood for sawmill and/or various pulping processes. It generally includes storage of the logs on land or in water, removal of the bark from the logs in the presence or absence of water, chipping and chip screening, and storage. Pulp mills often debark and chip the entire log while sawmills generally debark the log and chip the slabs and waste wood left over from lumber manufacture. A typical pulp mill woodroom system with drum debarking is illustrated in Figure 2.

Canadian mills practice both wet and dry debarking, the principle types being hydraulic, mechanical ring and drum debarkers. Because of site specific variations, as discussed in Section 3, it is somewhat difficult to generalize about the advantages and disadvantages of wet debarking compared to dry debarking methods. However, those most frequently encountered are as follows:

TABLE 1. PROCESS EFFECTS OF BARK IN BLEACHED KRAFT PULP PRODUCTION

<u>Item</u>	<u>Wawer (1975)</u>	<u>Horn & Auchter (1972)</u>	<u>Thomas & Howse (1975)</u>	<u>Keays & Hatton (1974)</u>
Pulp Yield	For 3 to 6% bark, a decrease of 3.8%/1% bark ¹	For 10% bark, a decrease of 0.5%/1% bark	Depends on recovery or digester limit	Depends on recovery or digester limit
Active Alkali Increase	0.35%/1% bark	0.25%/1% bark	0.6%/1% bark	0.33%/1% bark
Bleach Chemical Increase	0.3%/1% bark	0.03%/1% bark	1%/1% bark	quotes Horn & Auchter
Pulp Strength	NI ²	No differences for 10% bark	Slight reduction, not evident at low levels of bark	Negligible effects for 10% bark
Pulp dirt	Off quality at greater than 3% bark inclusion	Unacceptable at 10% bark ³	No significant increase	NI
Other effects	- increase in black liquor solids - more frequent evaporator boil-outs - cooking more difficult to control - 9 to 11% bark gave severe process and operation problems	- black liquor solids increase of 14% for 10% bark	- dirt problem with unbleached grades - possible fisheye problems - possible effects on evaporators, foaming and drainage	NI

¹A 3.8% decrease in yield with a 1% bark content in the chips.

²Not included.

³Claim this can be corrected with additional centricleaning capacity.

TABLE 2. ECONOMIC EFFECTS OF BARK IN BLEACHED KRAFT PULP PRODUCTION

<u>Source</u>	<u>Conditions</u>	<u>Economic Effect (\$/m³/1% Bark)*</u>	
		<u>Savings</u>	<u>Additional Cost</u>
Wawer (1975)	Bark Content of 3 to 6%	-	0.81
Auchter & Horn (1973)**	Bark Content of 10%	-	0.12
Thomas & Howse (1975)	Not Recovery Boiler or Digester Limited	0.07	-
	Recovery Boiler or Digester Limited	-	0.11
Keays & Hatton (1974)	As per Thomas & Howse	-	-
Calvert & Garlicki (1974)	-	-	0.94

* Dollars per cubic metre of wood processed per 1% bark content in the chips

**Also claim a net saving of \$0.97/m³ of debarking is eliminated.

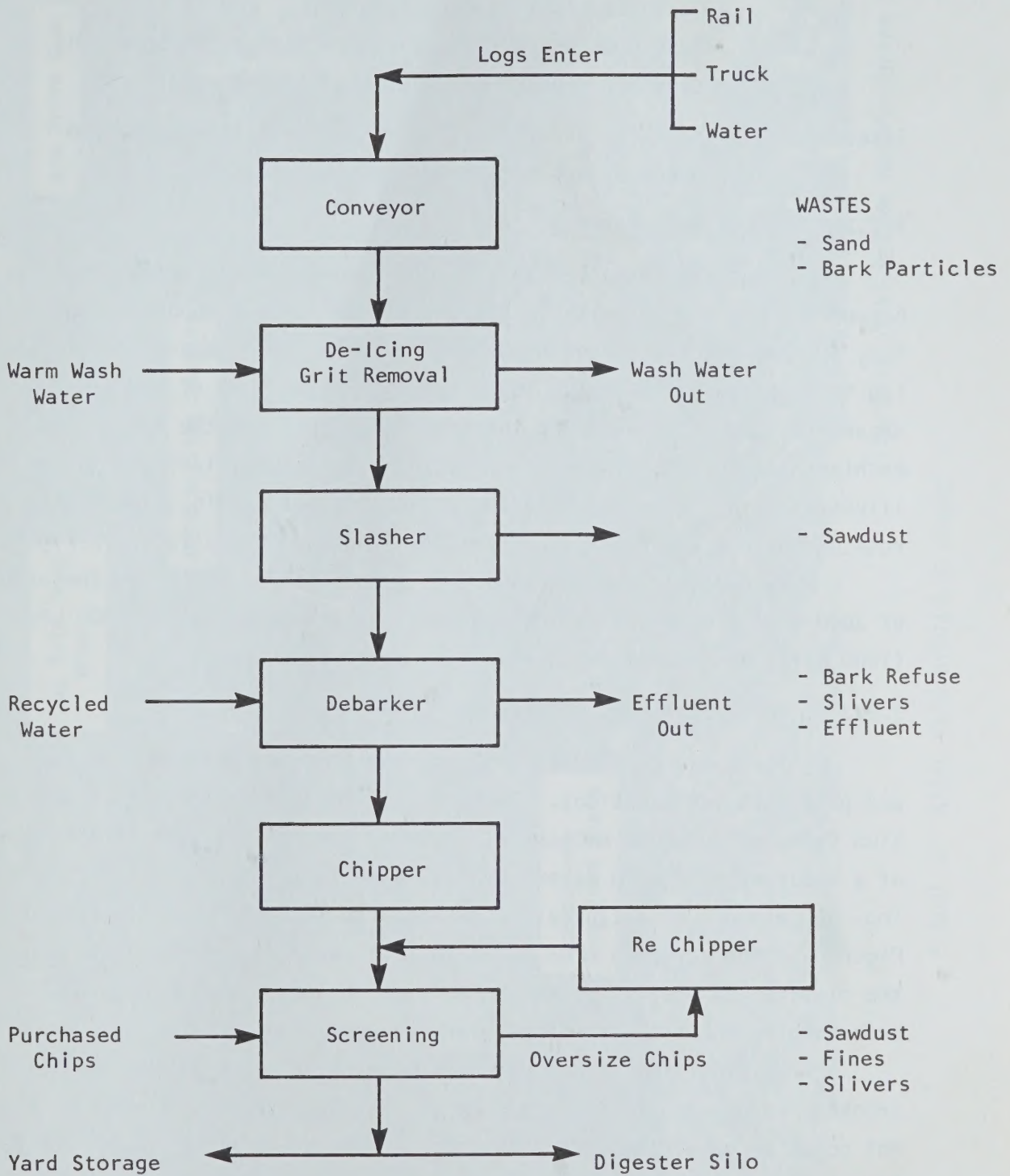


FIGURE 2. WOOD PREPARATION (after Environment Canada, 1974)

Advantages - generally able to achieve more complete bark removal;
 - less wood loss in bark removal;
 - less dirt and grit in the bark and chip system; and
 - does not require prethawing of frozen wood.

Disadvantages - produces an effluent which requires treatment; and
 - produces wet bark with a lower fuel value.

2.2.2 Hydraulic debarkers

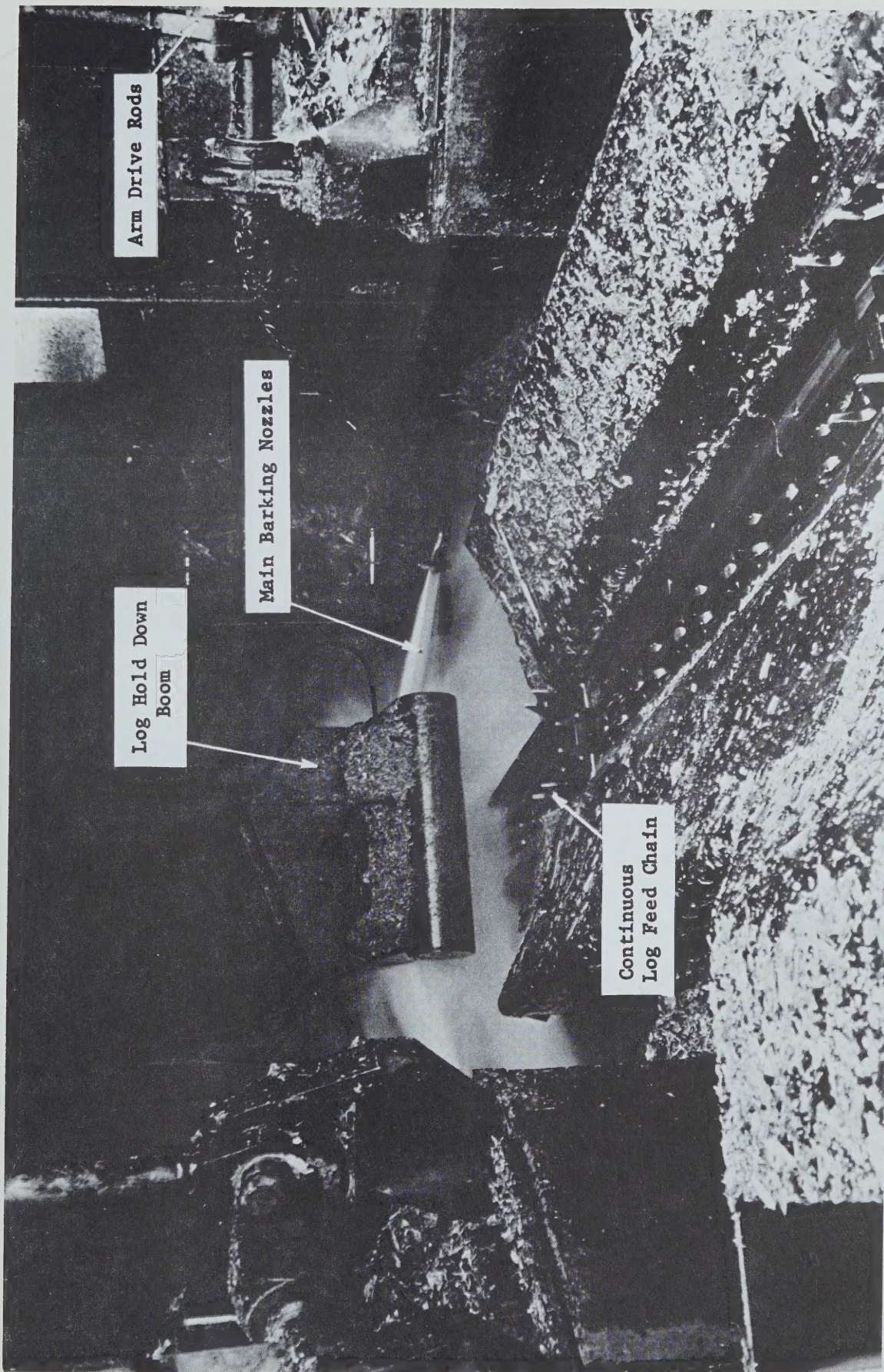
These are installed in mills on the west coast primarily because they are more suitable for the larger western wood species. They operate by directing a high velocity water spray against a single log to blast away the bark. There are two basic types of hydraulic debarkers, the axial-feed and the traversing-jet. In the axial-feed machine, nozzles are fixed to a rotating ring or oscillating arms, as illustrated in Figure 3. With the traversing-jet machine, the log is rotated while a water jet traverses its length as illustrated in Figure 4.

Hydraulic debarkers use large quantities of water, in the order of 3000-6000 l/min (800 to 1600 US gpm), at pressures up to 12000 kPa (1800 psi), and therefore have a high energy consumption.

2.2.3 Mechanical ring debarkers

These are popular in eastern sawmills, and western sawmill and pulp mill installations. The general trend in the west is conversion from hydraulic to mechanical systems. Mechanical debarkers consist of a rotating ring with several radial arms that scrape the bark off the log. An example of a typical mechanical ring debarker is illustrated in Figure 5. The scraping arms shown in this photograph are adjustable to the diameter of the log. The pressure of the arms is also adjustable according to the strength of the bark-to-wood bond.

Difficulties in mechanical debarking are experienced with crooked, rough and frozen logs, and with stringy bark such as cedar. Hot ponds or presteaming chambers are often used as pretreatment for frozen logs. Because of the abrading action, wood losses are normally higher than with hydraulic debarkers especially with frozen logs, as noted by Calvert and Garlicki (1974).



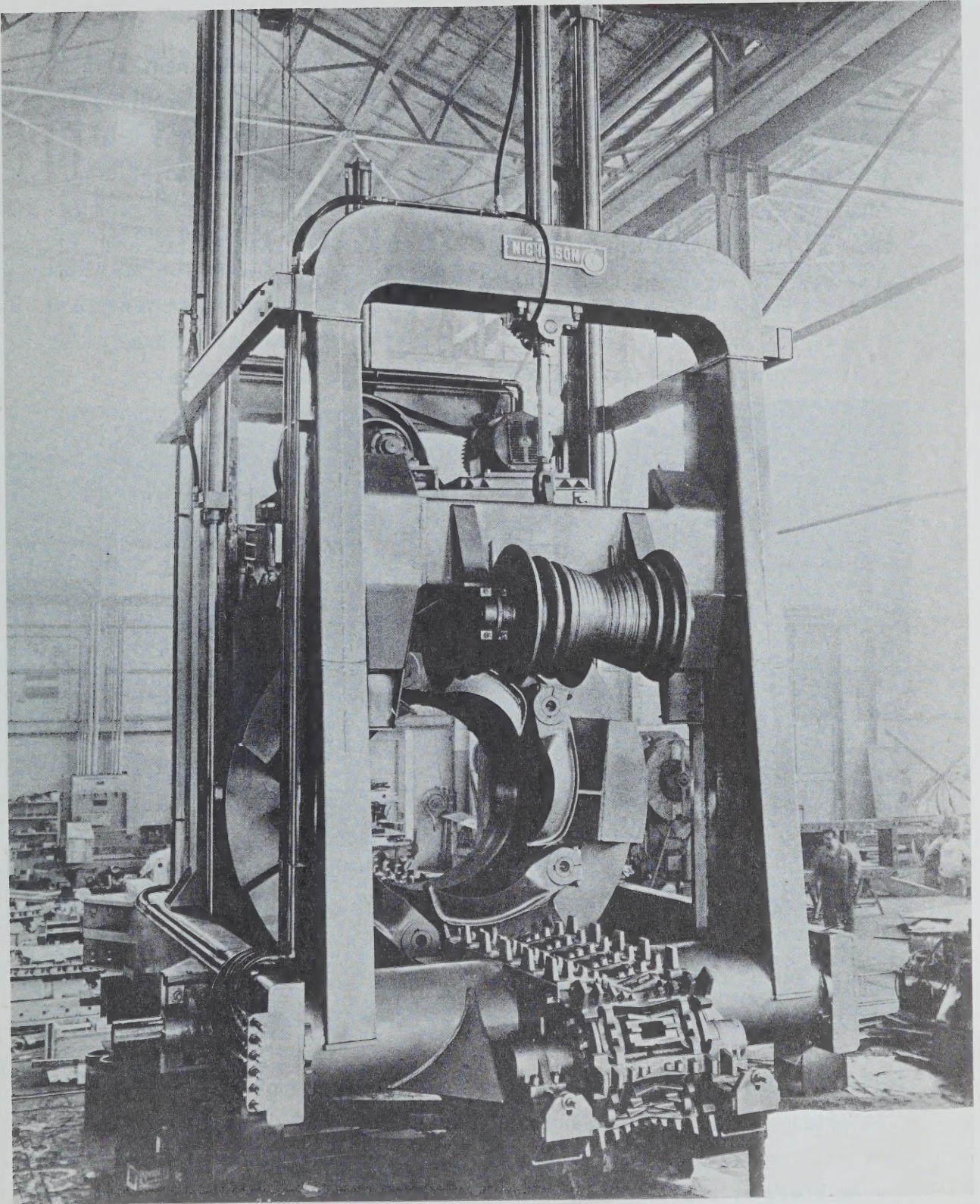
(Courtesy of Nicholson Manufacturing Co.)

FIGURE 3. AXIAL-FEED HYDRAULIC DEBARKER



(Courtesy of Black Clawson, Inc.)

FIGURE 4. TRAVERSING-JET HYDRAULIC DEBARKER



(Courtesy of Nicholson Manufacturing Company)

FIGURE 5. MECHANICAL RING DEBARKER

2.2.4 Drum debarkers

In North America, these debarkers are used predominantly in the northeast because they are the most efficient means of handling a large quantity of smaller diameter logs. An illustration of a drum debarker is presented in Figure 6. Logs are fed into one end of a rotating cylinder and exit from the other end. The tumbling action of the wood in the drum knocks the bark off the logs. Facilities are provided for recycling insufficiently debarked logs.



(Courtesy of MoDoMekan (Canada) Ltd.)

FIGURE 6. DRUM DEBARKER

The drums can be operated in a dry or a wet mode. With the wet system, water is sprayed into the inlet section of the drum to weaken the bark-to-wood bond. When the logs are frozen hot water is used, often in the form of hot mill effluent such as white water or alkaline extraction effluent. Water usage ranges from 1000 to 4000 l/min (260 to 1060 US gpm).

Most wet drum installations practice some effluent recycle. The dry system normally requires a greater drum capacity or lower debarking rates to achieve the same bark removal. As with mechanical debarkers, pretreatment is often necessary for frozen logs although steam can often be injected into the drum inlet.

There are two approaches to bark removal in the drum; the tumbling action where shorter logs tumble at random; and the parallel action where longer logs roll parallel to the drum axis. The parallel drums claim to help alleviate high wood losses due to log breakage and "brooming" (Ranhagen, 1971).

2.2.5 Other systems and new developments

Other types of debarkers which were not included in this report because of their limited use include the Rosserhead mechanical, pocket, knife and portable systems.

Novel approaches, still in the pilot plant stage, include bark removal after chipping, and pulping without bark removal. Interest in these is prompted by a desire to increase fibre recovery by utilizing the whole tree, including branches. Methods of bark removal after chipping by wet and dry means is being investigated by several organizations including PPRIC (Berlyn and Hutchinson, 1976) and by the USDA Forest Service (Arola et al., 1976).

Pulping without prior bark removal places increased emphasis on subsequent pulp cleaning systems. This alternative has been studied by the authors discussed in section 2.1 (Wawer, 1975; Auchter and Horn, 1973; Thomas and Howse, 1975; Keays and Hatton, 1974). Perhaps the most optimistic projection is that of Auchter and Horn (1973) who estimated \$0.97/m³ (\$2.75/cunit) savings by eliminating debarking. The majority of this saving is due to a substantial increase in yield on unbarked wood due to the absence of wood loss.

2.3 Effects of Variables

The major variables influencing the efficiency of debarking are the felling and debarking seasons, wood species, log quality and transportation and storage methods. A brief discussion of these variables follows; further discussion is included in section 5.1.

2.3.1 Seasonal effects

Among the mills surveyed, the differences between summer and winter cut wood was one of the most important variables affecting the ease of bark removal. Winter cut wood is harder to debark since the cambium layer becomes inactive thereby increasing the bark-to-wood bond. Measurements made by Berlyn (January, 1965) have indicated that this bonding strength can be two and one-half times greater during the dormant winter season. Seasonal effects can also vary with species; Berlyn measured a 100% seasonal difference in bond strength for spruce and a 200% difference for poplar.

Frozen logs exhibit a bark-to-wood bonding strength of two and one-half to five times that for thawed logs (Berlyn, August, 1965). Wet debarking is able to overcome this by using heated water, while dry debarking normally use a pre-thawing stage employing hot water soaking or steam. Calvert and Garlicki (1974) studied the mechanical debarking of frozen wood without pretreatment. With optimum settings, they were able to achieve desired residual bark standards with pulpwood but not with sawlogs because of the lower volume of chippable material and therefore higher bark residual. They also noted higher wood losses with frozen logs.

2.3.2 Species effects

Berlyn (January, 1965) has determined the bark-to-wood bonding strengths of several species. He concluded that the difference in bonding strengths between species was small in the growing season, but was pronounced during the dormant season. There is some disagreement in the literature on the relative difficulty of debarking different species. Calvert and Garlicki (1974) state that balsam fir was more difficult to debark than spruce, while Berlyn (1969) found the reverse. However, the

general consensus is that hardwoods are more difficult to debark than softwoods particularly with dry systems.

2.3.3 Log quality

While defects such as irregular shape, fissures, stubs and rot are of less concern with hydraulic and drum debarking, they can dramatically influence the effectiveness of mechanical debarkers. This was the most common reason given by various pulp mills for mechanical debarking difficulties. Mechanical debarker performance at sawmills is better due to higher quality logs. With further decreasing log quality in many areas of Canada this variable will become more important.

2.3.4 Transport and storage

The mode of log transport to the mill and type of storage can significantly affect bark coverage on the log, the adhesion of bark and the quantity of dirt carryover. Coastal installations generally practice water transport and storage, while inland mills generally transport their wood by truck and rail, and store dry. Some of the latter also use hot ponds for de-icing.

Estimates of bark coverage in this study ranged from 90 to 100% for truck driven and water stored logs. Dobie and Wright (1975) concluded that for water driven coastal species, average bark coverages bore little relationship to transport distance or method. Bark coverage averaged from 30 to 85%. In addition to its effect on the watercourse environment, bark loss obviously has significant impact on debarking requirements and hog fuel quality and recovery.

Mills contacted in this study indicated that logs that had been allowed to dry out over long periods of dry land storage (one year or more) were much more difficult to debark than logs stored for short periods (three months or less). While there are little available data on this aspect, Perem (1958) indicated that rapid drying of felled trees hinders bark removal. However, he also indicated that trees cut during the winter season may be debarked more easily if stored until the following summer.

Dirt in hog fuel and wood chips may influence their acceptability for subsequent processing. While wet storage can result in sediment

being imbedded in the bark, particularly during spring runoff in river storage situations, in general it has a beneficial effect by removing some of the dirt picked up during logging and sorting functions.

2.4 Energy Requirements

Debarking energy requirements can have a major impact on operating costs. Comparison between wet and dry debarking is made on the basis of unit power usage or power used per unit of production. While installed power figures are generally available from manufacturers, there is very little information available on unit power usage.

Unit power requirements in this study are based on data obtained from various mill installations and are summarized in Table 3. From the range of values encountered, it is evident that there is variability in energy requirements between different installations with the same type of debarking. Average values indicate that mechanical debarking is notably the most efficient in its energy demand. Hydraulic and drum debarking are similar in their unit power demand and several times the requirement for mechanical debarking. While conversion from hydraulic to mechanical debarking would result in a significant power saving, conversion from wet to dry drum debarking would yield little change. In converting from a wet to a dry drum system, there is generally an energy saving due to elimination of the flumes, bark drainer, presses, and effluent screening system; however, this is offset by an increase in power required per unit of production since the wood throughput for the same drum capacity is generally lower with the dry system.

TABLE 3. SUMMARY OF DEBARKING POWER REQUIREMENTS

<u>Type of Debarking</u>	<u>Number of Installations</u>	<u>Power Used (kWh/m³)*</u>	
		<u>Average</u>	<u>Range</u>
Mechanical Ring	7	1.2	0.8- 1.5
Hydraulic	7	8.1	4.1-16.6
Wet Drum	4	7.7	5.1-10.6
Dry Drum	4	7.9	4.3-10.2

* m³ of wood produced.

A more detailed presentation of the data, including debarking rates, debarker type and power usage for each installation is summarized in Appendix 1. In general, for hydraulic debarking, about 10% of the power requirement is for associated equipment such as bark pressing and screening. For drum debarking about 20% of the power demand is due to auxiliary equipment such as flumes, presses and screens. Based on mill measurements, power consumption averaged about 75% of the installed value for each type of debarker and this value was used for estimating purposes in subsequent sections of this report.

2.5 Hog Fuel and Energy Recovery

Until recently, bark was regarded as a disposal problem. However, with the rapidly rising cost of energy it is receiving increased attention as a viable and important source of energy. The composition, quality and consumption of hog fuel varies widely within the industry. While hog fuel from a pulp mill is predominately bark, that from a sawmill may include a mixture of bark, sawdust and wood shavings. Data for eastern and western species (Canadian Forestry Service, 1970; Dobie, 1975) indicate that bark can range from 9 to 24% of the total log volume. Based on Dobie's (1975) estimates, from one-half to two-thirds of sawmill hog fuel can be made up of sawdust and wood shavings. Many of the sawmills and pulp mills contacted in this study mixed hog fuel from a number of sources.

The advantages and disadvantages of hog fuel utilization are summarized as follows:

- Advantages
- it is a relatively inexpensive energy source; and
 - it has the potential for making sectors of the pulp and paper industry energy self-sufficient.
- Disadvantages
- it presents handling and storage problems;
 - it can present burning, erosion and corrosion problems because of dirt, salt or moisture content; and
 - it results in boiler particulate emissions.

The influence of debarking on hog fuel quality is discussed in more detail in Sections 4.5 to 4.7.

Neill (1976), in an extensive survey of hog fuel usage, reported that the total quantity produced in Canada is over 30 million tons per annum. He estimated that Canadian mills are using approximately 45% of this quantity for energy generation with the remainder being incinerated (40%) or landfilled (12%) with small amounts (3%) going to other uses such as mulch and particle board. Based on Neill's data, the average production of hog fuel from a pulp mill is 80 kg/m^3 (500 lb/cunit) at an average moisture content of 50% by weight on a wet basis.

The market value of hog fuel can vary widely, especially if transportation costs are considered. Based on an oven dry heat value of 4770 kcal/kg (8600 Btu/lb), a moisture content of 50% and an oil cost of \$0.07/l (\$0.25/USG), hog fuel has an equivalent value of \$9.00/tonne (\$8.20/ton).

It is instructive to compare the potential for energy generation from pulp mill hog fuel, a byproduct of wood preparation, to the energy consumption in the preparation of wood. This comparison is summarized in Appendix 2 and illustrates that the surplus energy potential is about 20 times that consumed in the woodroom and 30 to 200 times that required for debarking.

3. MILL EXPERIENCES WITH WET AND DRY DEBARKING

3.1 General

The Organization for Economic Cooperation and Development (1973) reviewed debarking practices in a number of countries. For Canada, 75% of the pulp mills practiced debarking at the millsite and 93% of these had wet debarking installations. In recent years this 93% has been reduced considerably as mills convert to dry debarking.

The following discussions present the experiences of several mills including bleached kraft, newsprint and sulphite pulp mills as well as sawmills, which fall into one of the following categories:

- converted from wet to dry debarking;
- had wet and dry debarking installations operating at the same mill; or
- had retained a wet debarking system and installed a simple treatment and recycle system.

In evaluating the relative merits of wet and dry debarking, product quality and effluent treatment on a site specific basis, the following were used as a basis for comparison:

- All costs are expressed in 1976/77 values.
- Unit costs for power, labour and steam are based on current values for the mill under consideration.
- Annual depreciation charges are calculated as 10% of the capital cost.
- Energy recovery from hog fuel is based on equivalent oil savings at \$0.07/litre (\$0.25/USG). On this basis, the value of hog fuel with a 50% moisture content is about \$9/tonne (\$8.20/ton).
- Residual bark is calculated as the oven dry weight of bark per oven dry weight of chips. The economic consequence of bark is based on the values established in Section 2.1.
- Debarking power draw averages 75% of installed power.

3.2 Kraft Mills

Mill 1

This is a bleached kraft pulp mill producing 770 ADMTPD (850 ADTPD) of soft-wood market pulp. It debarks 3700 m³/day (1300 cunits/day) of black and white spruce and Jack pine using four Manitowoc drums

each 3.7 m diameter by 21 m long (12 ft x 68 ft). The wood is truck hauled and dry stored. The system was installed as wet drums in 1967 and converted to dry drums in 1975.

In the wet system, water was injected into the drums and the bark conveyed by flumes to a screen. The bark fines and water passed through a rotary drainer then to primary settling basins.

In converting from the wet to the dry system, the drum sprays were removed, the flumes replaced with vibratory conveyors and the drainers and presses by-passed. A small amount of steam is introduced at the drum inlets for dust control; however, this is insufficient for de-icing purposes. Washing sprays, using hot caustic extraction effluent, are installed on the conveyor lines from the drums to the chippers to remove grit from the logs.

The major reason for conversion was effluent control. This mill was experiencing high BOD discharge following secondary treatment and was focussing on in-mill changes to reduce raw effluent losses. Other justifications for conversion included elimination of problems with hog pressing and the desire for greater energy recovery from hog fuel.

Effects of conversion:

1. Product quality - Rather than decrease debarking rates or install additional drum capacity this mill decided to maintain the same debarking rates after conversion at the expense of less efficient debarking. The relevant data summarized in Table 4 indicates that residual bark based on yearly averages has increased from 0.9 to 2.4%. Bark removal efficiency for both wet and dry debarking is also found to be seasonally dependent. During the summer months, dry debarked wood averaged 1.5 times the bark content of wet debarked wood, while during the cold and intermediate months, the ratio was 3 to 4 times.

The effects of higher residual bark content on pulp yield and chemical consumption have not been evaluated by the mill. There has been no increase in spec counts in the final product because of adequate bleached stock cleaner capacity and the fact that unbleached screening rejects are discarded. With dry debarking, the mill strives to maintain less than 4% bark in the winter and less than 2% in the summer.

TABLE 4. COMPARISON OF CHIP RESIDUAL BARK CONTENT BEFORE AND AFTER CONVERSION FROM WET TO DRY DRUM DEBARKING FOR MILL 1

<u>Item</u>	<u>Wet Drum Debarking</u>	<u>Dry Drum Debarking</u>
Year for Comparison	1974	1976
Average Wood Processed, m ³ /hr	147	143
Residual Bark Percentage		
Intermediate Months	0.7	2.9
Cold Months	1.2	3.8
Warm Months	<u>0.7</u>	<u>1.3</u>
Average/Year	0.9	2.4

2. Effluent treatment - The major benefits of the elimination of debarker effluent with regard to effluent treatment has been a reduction of BOD discharged, a reduction in frequency of cleaning out the settling basin and a substantial reduction in aeration lagoon nutrient requirements. Due to the elimination of debarker effluent and the addition of a third brown stock washer, the average mill BOD₅ discharge was reduced from 53.5 kg/ADMT (107 lb/ADT) to 39 kg/ADMT (78 lb/ADT). It was estimated that debarker effluent was responsible for two-thirds of this reduction. Because BOD was no longer a limitation, lagoon stability improved and nutrient requirements were practically eliminated.

3. Costs - A summary of the economic effects of the conversion is included in Table 5. It is evident that the estimated cost due to additional bark in the chips and the savings due to greater hog fuel utilization are much more significant than the other cost items. The economic consequence of higher bark residuals must be evaluated by the mill in question; the wide range encountered in the literature reflects the site specific nature of this factor. Estimates have been based on the fact that this particular mill is currently limited in recovery boiler capacity. As the mill is expanding its recovery capacity this cost factor will be eliminated and a net savings due to conversion of about \$0.7/m³ (\$2/cunit) will be realized.

TABLE 5. ESTIMATED ECONOMIC EFFECTS OF CONVERSION FROM WET TO DRY DRUM DEBARKING FOR MILL 1

<u>Item</u>	<u>Additional Cost (\$/m³)</u>	<u>Savings (\$/m³)</u>
Additional Bark Residual (2.4% vs 0.9%)	0.2 - 1.4	
Energy Savings and Reduced Disposal Cost Due to Greater Hog Fuel Usage (80% vs. 50%)		0.71
Additional Maintenance Due to Grit	0.06	
Savings in Effluent Treatment Costs		0.11
Additional Depreciation Due to Conversion	<u>0.05</u> 0.3 - 1.5	<u>0.8</u>

More hog fuel is utilized with dry debarking since the bark presses were formerly a limitation. Hog fuel utilization has increased from approximately 50% to 80% or greater, resulting in significant energy savings and reduced disposal cost.

Operating costs were not itemized for debarking; however, mill opinion indicated these were generally similar for the wet and dry systems. One aspect singled out for further investigation was maintenance costs. While maintenance costs have been reduced in some areas due to the elimination of the bark presses, bark drainer and flumes, they have increased for chipper and shredder knife replacements, wear in the hog fuel conveying system and added frequency of boiler cleaning due to a significant increase in the sand and grit carryover. With the wet system, this grit was washed out of the bark and purged with the effluent. This grit problem has been only partially alleviated with the log washers.

Credits in effluent treatment costs are based on a nutrient cost savings of approximately \$800/day. It was conservatively assumed that the elimination of debarker effluent was responsible for half of these savings.

Depreciation is based on a capital cost of \$500,000 which includes the cost of converting the drums and replacing the flumes with conveyors.

Mill 2

This mill produces 530 ADMPD (580 ADTPD) of bleached hardwood and softwood market pulp. A summary of debarking parameters is included in Table 6. The original system consisted of four wet drums. In 1975, one drum was converted from wet to dry and another was replaced with a dry drum; thus the system is presently operating with two wet and two dry drums. The existing bark flumes were replaced with belt conveyors. Bark from the wet and dry systems presently is mixed so that bark pressing is only occasionally needed. A water shower is located on the log conveyor feeding the wet and dry drums for grit removal and de-icing. Steam is periodically used in the dry drums for de-icing.

TABLE 6. SUMMARY OF DEBARKING PARAMETERS FOR MILL 2

<u>Item</u>	<u>Wet System</u>	<u>Dry System</u>
Debarker Type and Size	2 Hooper Hanson Drums, 3.7 m dia x 19.8 m	2 CIR Welldrums, 3.7 m dia x 19.8 m
Wood Species and Size	Poplar, Maple, Birch, Softwood 20 cm dia x 2.4 m	
Winter Hardwood Debarking Rates, m ³ /hr	75.6	49.3
Installed Power, kW		
Drums	597	522
Associated Equipment	<u>52</u>	<u>17</u>
	649	539
Power Consumption, kWh/m ³	6.4	8.2

Decreased water use and mill effluent load, recovery of additional bark for burning, drier hog fuel, and less reliance on bark presses were the reasons stated for the conversion.

Effects of conversion:

1. Product quality - Simultaneous measurements of the debarking effectiveness and production rates were made by the mill for the wet and

dry drums after the conversion (Table 7). These measurements were for hardwood debarking during the winter months. Summer figures and data for softwood debarking were not available, but differences for these would be less pronounced.

Comparison of wet and dry debarking rates in Table 7 indicates that throughput is species dependent and reduced with dry debarking. On average, dry debarking rates dropped by one-third. Despite the lower processing rate, residual bark after dry debarking is more than double the previous average.

TABLE 7. COMPARISON OF DEBARKING RATES AND RESIDUAL BARK FOR WET AND DRY DRUMS AT MILL 2

<u>Item</u>	<u>Wet Drums</u>		<u>Dry Drums</u>	
Drums Operating	2 Drums 3.7 m dia x 20 m		2 Drums 3.7 dia x 20 m	
Debarking Rate and Residual Bark for Species*:				
Poplar - m ³ /hr	15.3		10.5	
- % bark		0.6		1.5
Maple - m ³ /hr	22.4		18.1	
- % bark		0.2		0.5
Birch - m ³ /hr	37.9		20.7	
- % bark	<u> </u>	<u>0.4</u>	<u> </u>	<u>0.8</u>
Average Debarking Rate, m ³ /hr	75.6		49.3	
Average Residual Bark, %		0.4		0.9

* Data for winter debarking

2. Mill effluent - The conversion to dry drums and replacement of flumes with dry conveyors has completely eliminated effluent from the dry side. Since the woodroom effluent presently is treated with water extractors and is discharged to the mill effluent treatment system, the effects of conversion on treatment costs would be minimal.

3. Costs - Estimates of the effects of complete conversion from wet to dry debarking are based on the mill's partial conversion to dry debarking and summarized in Table 8.

TABLE 8. ESTIMATES OF THE ECONOMIC EFFECTS OF THE CONVERSION FROM WET TO DRY DEBARKING FOR MILL 2

<u>Item</u>	<u>Additional Cost (\$/m³)</u>	<u>Savings (\$/m³)</u>
Increase in Operating Cost Due to Lower Dry Debarking Rates	0.11	
Additional Costs Due to Higher Bark Residuals (0.9% vs 0.5%)	0.06 - 0.46	
Additional Depreciation Due to Conversion	0.07	
Energy Savings Due to Drier Hog Fuel (45% vs 50% moisture)		0.11
	0.24 - 0.64	0.11

The economic consequence of conversion hinges upon the additional cost attributed to higher bark residuals. This cost factor has been based on the fact that the mill is currently limited in digester and recovery capacity. If mill evaluations revealed that this increase in residual bark was inconsequential, the additional cost and savings due to conversion would approximately balance.

The increase in operating cost has been based on the assumption that winter debarking rates are decreased by one-third and summer debarking rates are not affected by the conversion. Thus, the unit operating cost, estimated at \$0.42/m³ (\$1.20/cunit) for this mill, is increased by 25% over the year.

Depreciation charges have been based on a capital cost of \$600,000 for converting the drums from wet to dry mode and replacing the flumes with conveyors.

Increased energy recovery has been based on mill measurements which indicate a hog fuel moisture content of 45% after dry debarking without pressing compared to 50% after wet debarking with pressing.

3.3 Newsprint Mills

Mill 3

This mill produces 450 ADMTPD (500 ADTPD) of newsprint. Table 9 summarizes pertinent debarking parameters.

TABLE 9. SUMMARY OF DEBARKING PARAMETERS FOR MILL 3 BEFORE AND AFTER CONVERSION FROM WET TO DRY DRUM DEBARKING

<u>Item</u>	<u>Wet System</u>	<u>Dry System</u>
Debarker Type and Size	Ingersoll-Rand 3 - 3.7 m dia x 9.2 m 2 - 3 m dia x 9.2 m	Ingersoll-Rand 2 - 3.9 m dia x 27.5 m
Operators/Shift	7 1/2 - 8 1/2	3 1/2
Debarking Rates, m ³ /hr		
Summer	96	71
Winter	Down	57
Installed Power, kW		
Drums	520	660
Associated Equipment	130	310
	650	970
Power Consumption, kWh/m ³	5.0	10.2
Wood Pretreatment	None	1100 kg/hr of Steam for Each Drum
Wood Species and Size	70% Spruce, 30% Fir 18 cm x 2.4 m	25% Hemlock, 53% Spruce, 22% Fir 20 cm x 2.4 m

The conversion from wet to dry debarking was part of a modernization program involving the installation of a new wood handling system including woodyard, flume, pumps, conveyors, building, debarkers, bark handling system and flume water cleaning system. The previous system consisted of five wet drums installed between 1929 and 1960. The new debarking system installed in 1976 was consolidated to two larger dry drums.

With the old system, wood was only debarked during the summer months and storage was maintained for winter use. With the new system, wood is debarked year-round. During winter, steam is injected into the drums to overcome debarking difficulties with frozen wood. Despite this, winter rates are 20% lower than summer rates.

Bark residuals with the old and new systems have been maintained at 0.2% bark by sorting and recycling unsatisfactory logs to the drums. Because the new system is more streamlined and log sorting and bark handling have been simplified, the number of operators associated with debarking has been reduced by about one-half.

The major reason for the conversion to dry debarking during the modernization program was a need to reduce the mill effluent load and increase energy recovery from hog fuel.

Effects of conversion:

1. Product quality - Wet and dry debarking rates are not directly comparable because of changes in operating schedule and drum capacity. The mill has been able to maintain the same level of residual bark (0.2%) with dry debarking by doubling drum capacity per unit of production and recycling unsatisfactorily debarked logs.
2. Mill effluent - In the original system, the woodroom effluent consisted of flume and debarking drum wastewaters. In the new system, woodroom effluent is solely flume water. A comparison of effluent characteristics before and after the conversion (Table 10) indicates that flow has been substantially reduced but not eliminated and the flume water discharged is far from innocuous.

TABLE 10. WOODROOM EFFLUENT CHARACTERISTICS BEFORE AND AFTER CONVERSION FROM WET TO DRY DEBARKING FOR MILL 3

<u>Effluent Parameter</u>	<u>Before Conversion</u>	<u>After Conversion</u>	<u>Percent Reduction</u>
Flow, l/day	7.8×10^6	3.7×10^6	50
Suspended Solids, kg/day	12,700	3,200	75
BOD, kg/day	2,100	310	87
pH	5.8	5.3	-
Toxicity	Toxic	Toxic	-

3. Costs - While debarking operating costs are not directly comparable for the old and new systems, Table 11 provides an indication of the considerations involved when an old, less efficient installation is faced with conversion. Based on these figures the conversion has resulted in a net savings of about $\$0.2/\text{m}^3$ ($\$0.6/\text{cunit}$).

TABLE 11. ESTIMATED ECONOMIC EFFECTS OF CONVERSION FROM WET TO DRY DEBARKING FOR MILL 3

<u>Item</u>	<u>Additional Cost (\$/m³)</u>	<u>Savings (\$/m³)</u>
Additional Energy Consumption	0.18	
Energy Savings Due to Drier Hog Fuel (50% vs 64% moisture)		0.41
Additional Depreciation Charges	0.35	
Savings in Operating Labour		0.34
	<u>0.53</u>	<u>0.75</u>

Energy consumption has increased due to steam application to the drums during the winter months. Also, because of greater drum capacity and changes in the fluming and screening system, unit power consumption for debarking has doubled. However, this is more than balanced by an improvement in energy recovery due to drier hog fuel.

Depreciation costs have been based on a conversion cost of \$2 to \$3 million for debarking which was part of a \$7 million expenditure for

the entire woodroom. Because the new system is more automated, savings in operating labour roughly balance this additional depreciation cost.

3.4 Sulphite Mills

Mills 4, 5, 6

This company has three sulphite mills situated on the west coast. All three mills have approximately the same capacity for bleached market and dissolving pulp production. Each mill debarks its wood using both wet and dry debarking. The smaller diameter logs are dry debarked and the larger diameter logs are routed to the wet debarkers. The company is concerned about the effects of residual bark on pulp quality and has conducted comparative evaluations for wet and dry debarking. Operating costs were not sufficiently itemized to provide comparative values for wet and dry debarking. A summary of pertinent mill and debarking parameters is included in Table 12.

Comparison of wet and dry debarking:

The opinion expressed by all three mills was that the residual bark specifications (less than 0.5% bark) were more difficult to meet with dry debarking. Reasons given for this included the following:

- Many of their logs are rotted and misshapen causing more difficulty with dry debarkers.
- The dry debarking performance is more sensitive to operator and maintenance variables.

The grit problem noted with dry debarking by other mills was also mentioned, but of greater concern were oxylates and sclereids contained in the bark which can end up in the pulp. Oxylates consume bleaching chemicals and cause scaling, while sclereids lower pulp quality. It was felt that since both of these are unattached to the bark structure, there is greater opportunity of removal with wet debarking.

Table 13 summarizes mill data for residual bark in chips from wet to dry debarking. The data are based on mill analysis of composite samples taken over a five-week period during November and December, 1976, and indicate the difficulty of meeting residual bark specifications (less than 0.5%) with dry debarking.

TABLE 12. SUMMARY OF MILL AND DEBARKER PARAMETERS FOR MILLS 4, 5, 6

Item	Mill 4		Mill 5		Mill 6	
	Wet Debarking	Dry Debarking	Wet Debarking	Dry Debarking	Wet Debarking	Dry Debarking
Mill Production	410 ADMTPD of Bleached Sulfite Market Pulp		460 ADMTPD of Bleached Sulfite Market Pulp		430 ADMTPD of Bleached Sulfite Market Pulp	
Wood Species	Hemlock (60%), Balsam (38%) Spruce (2%)		Hemlock/Balsam (95%), Spruce (5%)		Hemlock (90%), Spruce/Alder (10%)	
Wood Transport and Storage	Water Driven and Stored		Truck and Water Transport Water and Land Stored		Truck, Rail, Water Transport Water and Land Storage	
Log Dia, cm	35	25	10 to 152	10 to 60	50	25
Type of Debarker and Year Installed	Bellingham Hydraulic 1952	Brunette Mech- anical Ring 1965	Bellingham Hydraulic 152 cm 1966	Nicholson Murdie Mech- anical Ring 66 cm 1965	Bellingham Hydraulic 1957	Fibre Making Dry Drum 37 cm Dia x 13.7 m 1957
Average Debarking Rates, m ³ /hr	161	72.5	89.2	45.9	56.4	24.4

TABLE 13. RESIDUAL BARK CONTENT IN CHIPS FROM WET AND DRY DEBARKED LOGS

<u>Mill</u>	<u>Average Bark Content (%)</u>	
	<u>Wet Debarking</u>	<u>Dry Debarking</u>
Mill 4	0.2	1.3
Mill 5	0.1	0.5
Sawmills Supplying Mill 6	0.3	0.4

Because the dry systems handle small diameter logs and the wet systems process larger diameter logs, one would expect a 25 to 50% higher bark residual with dry debarking for the same removal of bark from the log surface. However, residual bark after dry debarking is five to six times greater than that after wet debarking, indicative of a substantial performance difference.

By comparison, there is minimal difference in wet and dry debarked chip quality from the sawmills, implying that the poor performance of dry debarking at pulp mills is directly related to the poor quality wood that these mills receive in comparison to the sawmills.

3.5 Sawmills

Mill 7

This sawmill operates on the west coast and produces 354 Mm³ (150 MMbf) of lumber annually. Debarking is done in two subsystems. System A debarks 130 m³/hr (46 cunits/hr) of hemlock and balsam using a 152 cm Nicholson mechanical ring debarker. System B debarks 42.5 m³/hr (15 cunits/hr) of the same wood species using a 89 cm Burnette mechanical ring debarker. The Nicholson debarker was installed in 1973 and the Burnette in 1976 and both replaced Hansel wig-wag hydraulic debarkers. Production rates did not change following conversion. The mill burns some hog fuel to generate steam and barges the remainder of the hog fuel and the chip production to a nearby bleached kraft pulp mill.

Effect of conversion:

1. Product quality - The sawmill has not observed any effects of debarking on lumber quality, and the pulp mill has not experienced any problems with higher bark residuals in the chips.

Following conversion to dry debarking the dirt content of the hog fuel increased, resulting in a greater frequency of grate cleaning and oil consumption at the pulp mill. Hog fuel samples taken during July and August 1976 revealed that ash residue ranged from 2.2 to 13.0% and averaged 2.7%.

The pulp mill is concerned about hog fuel moisture not only from the energy recovery but also from the boiler emissions viewpoint. Mill studies revealed that above 55% moisture content, particulate emissions increased significantly. The fact that a large percentage of the hog fuel consists of shavings and sawdust has obviated the need for hog pressing. While dry debarking has resulted in drier bark, improvements in hog fuel moisture content due to dry debarking can be nullified by moisture accumulation in transport and storage.

2. Mill effluent - Although debarker effluent comprised only 15% of the total mill discharge, it was the predominant source of BOD, suspended solids and toxicity, since 80% of the total discharge consists of innocuous condenser cooling water.

3. Costs - The operating costs before and after conversion for the larger System A and smaller System B have been estimated and summarized in Table 14. Comparison reveals that the operating cost for dry debarking is about one-half to two-thirds that for wet debarking even after considering the additional depreciation charges due to the capital cost of conversion. The reduction of power costs, particularly the demand portion, is the major contributing factor. The economy of scale between Systems A and B is also apparent.

In converting from wet to dry debarking, power requirements dropped from 1324 kW (1775 HP) to 235 kW (315 HP) for System A and from 526 kW (705 HP) to 86 kW (115 HP) for System B. This has resulted in power costs for mechanical debarking being about one-sixth those for hydraulic debarking.

Labour requirements are the same for wet and dry debarking, both systems requiring one operator per shift.

Maintenance costs based on non-routine requirements are substantially lower with dry debarking, but to some degree reflect reduced

TABLE 14. COMPARISON OF WET AND DRY DEBARKING COSTS FOR MILL 7

<u>Item</u>	<u>Wet Debarking</u>		<u>Dry Debarking</u>	
	<u>System A</u>	<u>System B</u>	<u>System A</u>	<u>System B</u>
Type of Debarker	Hansel Wig-Wag Hydraulic	Hansel Wig-Wag Hydraulic	Nicholson Mechanical Ring (152 cm)	Brunette Mechanical Ring (89 cm)
Debarking Rate, m ³ /hr	130	43.3	130	43.3
Power costs: Demand, \$/m ³	0.16	0.19	0.03	0.03
Usage, \$/m ³	0.05	0.06	0.01	0.01
Total, \$/m ³	0.21	0.25	0.04	0.04
Operating Labour, \$/m ³	0.07	0.21	0.07	0.21
Maintenance Labour & Material, \$/m ³	NA ¹	0.11	0.01	0.04
Depreciation, \$/m ³	-	-	0.05	0.09
Total Operating Costs, \$/m ³	0.28	0.57	0.17	0.38
	+ Maintenance			

¹ Not available

requirements of new equipment. Depreciation costs are based on a capital cost of \$250,000 for converting System A and \$155,000 for converting System B.

Mill 8

This west coast sawmill produces 295 Mm³ (125 MMbf) of lumber annually from cedar, hemlock, balsam and spruce. The mill has two debarking systems, one of which was converted from wet to dry debarking in 1975 and the remaining wet system will be converted to dry debarking in 1977.

The wet debarker is a Simons wig-wag hydraulic unit installed in 1953 and capable of handling logs up to 183 cm (72 in) diameter. The dry debarker is a Nicholson Murdie mechanical ring with arms specifically designed for handling stringy cedar bark. The wet and dry systems each debark an average of 93.5 m³/hr (33 cunits/hr) of wood. Chips produced from debarked wood slabs are barged to a nearby pulp mill.

Hog fuel from the wet and dry debarking systems and other independent sawmills is used to produce steam and generate electricity on site. Before combustion, all of the hog fuel is mixed and sent to a pressing and drying system in order to maximize energy recovery and minimize boiler particulate emissions.

The mill considered the possibility of retaining wet debarking and installing an effluent treatment system. Conversion from wet to dry debarking was the more economic alternative.

Effects of conversion:

1. Product quality - The mill has not noted any effects of either wet or dry debarking on lumber quality.

The chips produced from wet and dry debarked wood are mixed before shipment to the pulp mill. No additional rejections or complaints about chip quality or residual bark have been noted as a result of the conversion.

The sawmill considers that hog fuel quality has deteriorated as a result of the conversion. Much of the silt and salt which was washed out of the bark with the wet system is now retained with the hog fuel. This results in additional maintenance in the powerhouse and hog system

and possibly adds to boiler emissions. The mill considered log washers but rejected them because of effluent treatment requirements.

2. Mill effluent - The mill unsuccessfully tried alternate screening systems as a method of reducing debarker effluent suspended solids to the regulatory level. It also compared the cost of conversion to dry debarking against the cost of primary and secondary treatment (screening, clarification, biological treatment). For this situation, the elimination of debarker effluent was the lower cost alternative.

3. Costs - Operating costs for the wet and dry debarking systems in concurrent operation are summarized in Table 15. Although the size of the logs debarked in each system is different, the debarking rates and type of wood debarked is the same. The cost for mechanical debarking is about two-thirds that of the hydraulic system even after considering the additional depreciation due to the capital cost of conversion. The reduction in power cost is the major contributing factor.

TABLE 15. COMPARISON OF OPERATING COSTS FOR HYDRAULIC AND MECHANICAL RING DEBARKERS FOR MILL 8

<u>Item</u>	<u>Wet System</u>	<u>Dry System</u>
Type of Debarker and Year Installed	Simons Wig-Wag Hydraulic (183 cm), 1953	Nicholson Murdie Mechanical Ring (127 cm), 1975
Debarking Rate, m ³ /hr	93.5	93.5
Power, \$/m ³	0.27	0.02
Operating Labour, \$/m ³	0.16	0.16
Maintenance Labour and Material, \$/m ³	0.16	0.19
Bark Pressing, \$/m ³	0.13	-
Depreciation, \$/m ³	-	0.11
Total Operating Cost, \$/m ³	0.72	0.48

Power costs have been based on a power load for hydraulic debarking of 15.3 kW/m³ and 1.5 kWh/m³ for mechanical debarking. Some power for hydraulic debarking is supplied by a steam turbine which drives the high pressure water pump, the remainder being supplied by purchased and generated electrical power.

Both systems require one operator per shift, two shifts per day and both exhibit similar maintenance requirements.

Depreciation is based on a capital cost for conversion of \$300,000. This additional cost is roughly balanced by a savings due to the elimination of bark pressing.

Mill 9

This west coast sawmill produces 43 Mm^3 (18 MMbf) of lumber annually, three-quarters from hemlock and one-quarter from cedar. It debarks hemlock but not cedar.

The Hansel hydraulic debarker was replaced in 1975 by a 152 cm diameter Nicholson Murdie mechanical ring debarker. Debarking rates average $108 \text{ m}^3/\text{hr}$ (38 cunits/hr) and are similar for wet and dry debarking.

All wood residue from lumber manufacture, which includes debarked hemlock and unbarked cedar, is chipped and barged to a nearby kraft pulp mill. Chip quality has not been a problem either before or after conversion.

With the wet debarking system, hog fuel was sent to a silvacultural division where products were extracted and pressed hog fuel was returned to the sawmill; therefore, hog moisture was not a problem. Presently, some hog fuel is burned in the sawmill boilers to generate steam, some is barged to the pulp mill and some sold as mulch.

The decision to convert was based on reduction of effluent.

Effects of conversion:

The mill is satisfied with the mechanical debarker operation and has not experienced any adverse effects of the conversion on lumber, chip or hog fuel quality.

The conversion has eliminated the major source of mill effluent and has reduced the boiler particulate emission by lowering mill steam demand. Steam was formally required by the turbines driving the hydraulic debarker pumps.

Operating costs before and after conversion were not available. The capital cost of conversion in 1975 was \$530,000.

3.6 Special Cases

Mills 10 and 11

Mills 10 and 11 are two small west coast sawmills. Both debark cedar using a hydraulic debarker. A summary of the debarking system parameters for each mill is included in Table 16.

These mills were identified as special cases; faced with a debarker effluent problem, they decided to adopt a closed effluent treatment and recycle system rather than convert to dry debarking. Both systems were relatively inexpensive and consist of simple screening and clarification to remove suspended solids before recycle. One of the treatment systems is described in detail in Section 6.3.2 (Mill 11).

TABLE 16. SUMMARY OF DEBARKING SYSTEM PARAMETERS FOR MILLS 10 AND 11

<u>Item</u>	<u>Mill 10</u>	<u>Mill 11</u>
Mill Production, Mm ³ /yr	125	106
Wood Species	Western red cedar	Western red cedar
Log Dia, cm	15 - 150	15 - 183
Type of Debarker and Year Installed	Hansel Wig-Wag Hydraulic, 1962	Bellingham Hydraulic, 1958
Average Debarking Rate, m ³ /hr	139	40

The following reasons were given for retaining hydraulic debarking rather than converting:

- Both mills expressed concern over the ability to handle cedar with a mechanical debarker due to fouling of the mechanical ring with stringy cedar bark and high wood loss with break-up of mature logs.
- Both mills supply chips to kraft pulp mills and are required to meet a residual bark level of 0.2%, which would be difficult to meet with mechanical debarking, especially if logs susceptible to break-up by-passed the debarker. Mill 10 felt that this residual bark requirement was much too stringent especially in view of the recent report on successful kraft pulping of 40% undebarked cedar (Thomas and Davis, 1974).

- Capital cost requirement for installing an effluent treatment and recycle system were considerably lower than the cost of converting to mechanical debarking.

Effects of recycle:

Mill 10 has noted much greater wear of the high pressure debarker pump impeller and greater wear and plugging of debarker nozzles because of solids in recycled effluent.

Mill 11 experienced similar problems with wear and as a result installed a stainless steel debarker pump impeller and carbide tip nozzles. With this modification, they consider that maintenance costs and downtime are about the same as prior to recycle.

The capital cost for the treatment system for Mill 10 was \$150,000 in 1974. The additional maintenance costs due to recycle have not been fully evaluated for Mill 10 since the recycle system has only been in operation for six months. These can be assumed to be short term if methods similar to Mill 11 are adopted. The operating costs for the Mill 10 treatment system including depreciation are estimated to be \$0.06/m³ (\$0.18/cunit). Based on debarking costs summarized in Section 7.1, this would add about 15% to the debarking operating cost.

Mill 11 installed its system for \$34,000 in 1974. It was able to keep the cost low by obtaining much of the equipment from salvage.

4. EFFECTS ON PRODUCT QUALITY

4.1 General

In Section 3, areas of concern with regard to chip or hog fuel quality have been identified. In most cases, the effect of debarking on product quality was a primary concern because of its effect on pulp marketability and hog fuel acceptability.

The important elements of product quality were identified as the residual bark and salt content of the chips, wood loss, and the dirt, salt and moisture content of the hog fuel. Some of these product quality considerations were discussed on a site specific basis in Section 3. This section endeavours to provide a more general perspective by sampling and testing a representative cross section of mills with wet or dry debarking installations. This is not an exhaustive survey but one designed to identify problem areas and provide a comparative basis where mill and literature information is lacking.

Daily samples were taken over five days of normal operation at each installation. Mills sampled included three sawmills (Mills A, B, G), three bleached kraft pulp mills (Mills C, F, I), two newsprint mills (Mills H and E) and a sulphite mill (Mill D). These included two hydraulic, four mechanical ring, three wet drum and two dry drum debarking installations in eastern and western Canada. All of the wood was debarked between January and April 1977 and was cut in the summer and autumn of 1976.

Wood species included an eastern hardwood mix, eastern softwoods (pine, spruce, balsam) and western softwood (hemlock, balsam). Logs debarked in the east averaged 13 to 26 cm (5 to 10 inches) diameter, while logs debarked in the west averaged 26 to 60 cm (10 to 24 inches) diameter. Installations sampled on the west coast used water transport and storage, while those in the east used dry transport and storage. Debarking rates ranged from 76 to 210 m³/hr (27 to 74 cunits/hr) for hydraulic debarking, 31 to 65 m³/hr (11 to 23 cunits/hr) for mechanical debarking, and 34 to 42 m³/hr (12 to 15 cunits/hr) for drum debarking.

4.2 Experimental Methods

4.2.1 Sampling

Chip, bark and hog fuel samples were taken once per day over five days of normal steady-state operation, and were collected over approximately a one-half hour period. All samples were taken according to CPPA Standard Method D27P for flowing material. Compositing and subsampling was done according to the standard coning and quartering method outlined in the Tyler Sieve Handbook (W.S. Tyler Ltd., 1969).

Unscreened chips were sampled from the chipper discharge. Bark samples were generally taken directly from the bark conveyor leading from the debarker before any chip fines or other wood residue had been added. Hog samples were taken after the hog and either before or after pressing, and were representative of the end product for combustion. Individual sample volumes were 20 litres of chips and 10 litres of bark or hog fuel. The samples were stored in sealed plastic bags at 4°C prior to analysis.

4.2.2 Chip, bark and hog fuel analysis

Chip classification. Chip size classification was done according to CPPA Standard Methods using a Williams classifier. The sieve size range was selected according to a nominal chip size of 1.9 cm (3/4 inch) and shaking time was five minutes.

Bark in chips. In this study all chip fractions were analyzed for bark while residual bark data from other sources generally do not include analysis of the pin chips and fines fractions. Bark content was measured by cutting pieces of bark from the larger fractions. From the smaller pin chips and fines fractions, bark was segregated by visual means. Bark percentages were based on oven dry (O.D.) weight of bark per O.D. weight of chips.

Moisture content. Oven dry weights of bark and chips were determined by drying the samples to constant weight at 105°C. Oven dry weight percentages and moisture contents are based on a percentage of the original wet weight.

Salt Content. Four alternate methods were evaluated for the measurement of the sodium chloride (NaCl) content of chips and bark. These were:

1. High temperature ashing - Ashing the sample in a muffle furnace at 550°C overnight, washing the ash in 10 ml of 25% nitric acid (HNO_3), filtering and analyzing the filtrate for sodium (Na) by atomic adsorption spectrophotometry and chloride (Cl) by Standard Methods (APHA, 1976).
2. Low temperature ashing - The same procedure was followed as in high temperature ashing with the exception that the sample was ashed at 300°C overnight.
3. Shaking - Two grams of sample ground to minus 5 mm size in a Wiley mill were added to 100 ml of 5% HNO_3 , shaken for 15 minutes and filtered. The filtrate was made up to 250 ml and analyzed.
4. Boiling - The same procedure was followed as in shaking with the exception that the sample was boiled for 15 minutes. Three boiling extractions were done with the same sample and each extraction was analyzed.

Samples of bark and chips used in evaluating the analytical techniques were obtained from a west coast sawmill. Original samples and samples spiked with NaCl were used to evaluate recovery of NaCl. Results indicated that the high temperature ashing and shaking methods gave incomplete extraction. Boiling provided complete recovery, particularly after two extractions and was adopted as the best method for further analyses.

Since Na and Cl can be associated with other ions, the stoichiometric amount of NaCl was determined by using the limiting quantity of Na or Cl, and percentages were based on oven dry weights.

Equivalent Hardness. The calcium (Ca) and magnesium (Mg) content of the bark extract obtained by boiling was analyzed by atomic absorption spectrophotometry. These results were used to calculate the equivalent hardness (CaCO_3) content of the bark and expressed on the basis of oven dry weights.

Bark particulate content. The particulate content broadly referred to as dirt content is defined as the non-filterable, non-acid soluble residue in an ashed sample of bark.

The method consists of ashing a representative sample of bark in a muffle furnace at 550°C for a minimum of six hours. The majority of the ash is taken into solution by dissolving in 10 ml of 25% nitric acid. The mixture is then filtered through glass fibre filter paper and the filter dried at 105°C. The particulate stands out on the filter paper and can be removed by gentle brushing without disturbing the bottom ash layer impregnated in the filter paper. Percentages were based on oven dry weights of particulate and bark.

Wood loss. Wood loss represents the amount of wood removed from the logs in debarking. This was estimated by the following means:

- The bark residue from the debarker was analyzed for the ratio of oven dry weights of wood to bark in the residue.
- The formulae in report VP-X-97 by Environment Canada (Dobie and Wright, 1975) were used to calculate the theoretical volume percentage of bark to wood for the particular log species and average size. This theoretical volume percentage was converted to a weight percentage by multiplying by the ratio of average bark to wood density (1.2); allowing for the void volume due to fissures in the bark (25% void volume), and allowing for bark loss in transit. Bark loss in transit was estimated by visual and photographic means.
- Wood loss was estimated by multiplying the ratio of wood to bark in the residue by the actual ratio of bark to wood for the log. Thus, actual $\frac{\text{wt. bark}}{\text{wt. wood}}$ per log = theoretical $\frac{\text{volume bark}}{\text{volume wood}} \times 1.2 \times 0.75 \times \frac{\% \text{ bark coverage}}{100}$ and,
 $\% \text{ wood loss} = \text{actual } \frac{\text{wt. bark}}{\text{wt. wood}} \text{ for log} \times \frac{\text{wt. wood}}{\text{wt. bark}} \text{ for residue} \times 100.$

4.3 Chip Residual Bark Content

Concern over residual bark stems from its effect on pulping and bleach chemical consumption, pulp yield and pulp marketability as discussed in Section 2.1. This survey has been based on the analysis of

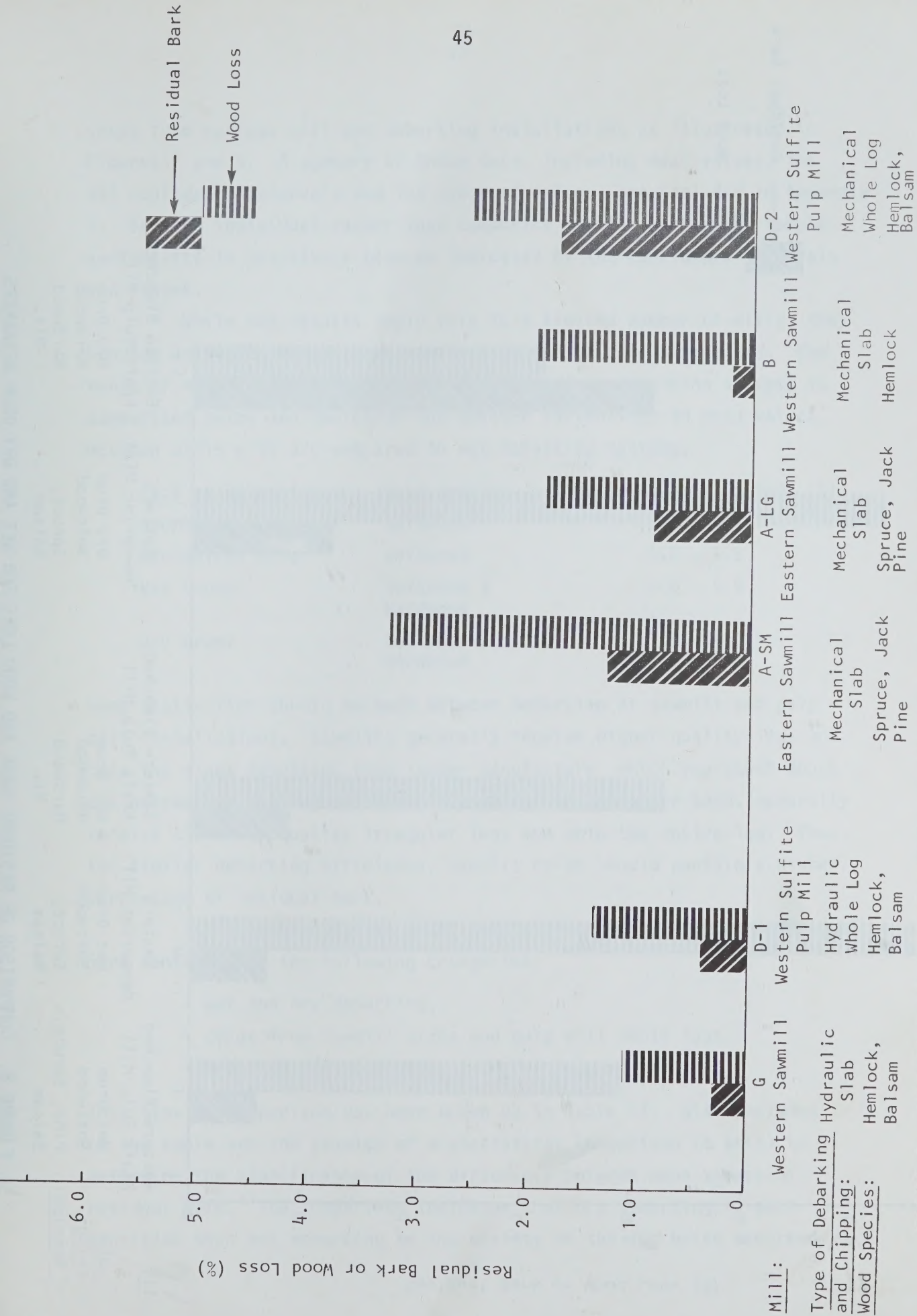


FIGURE 7. COMPARISON OF RESIDUAL BARK AND WOOD LOSS FOR HYDRAULIC AND MECHANICAL RING DEBARKERS

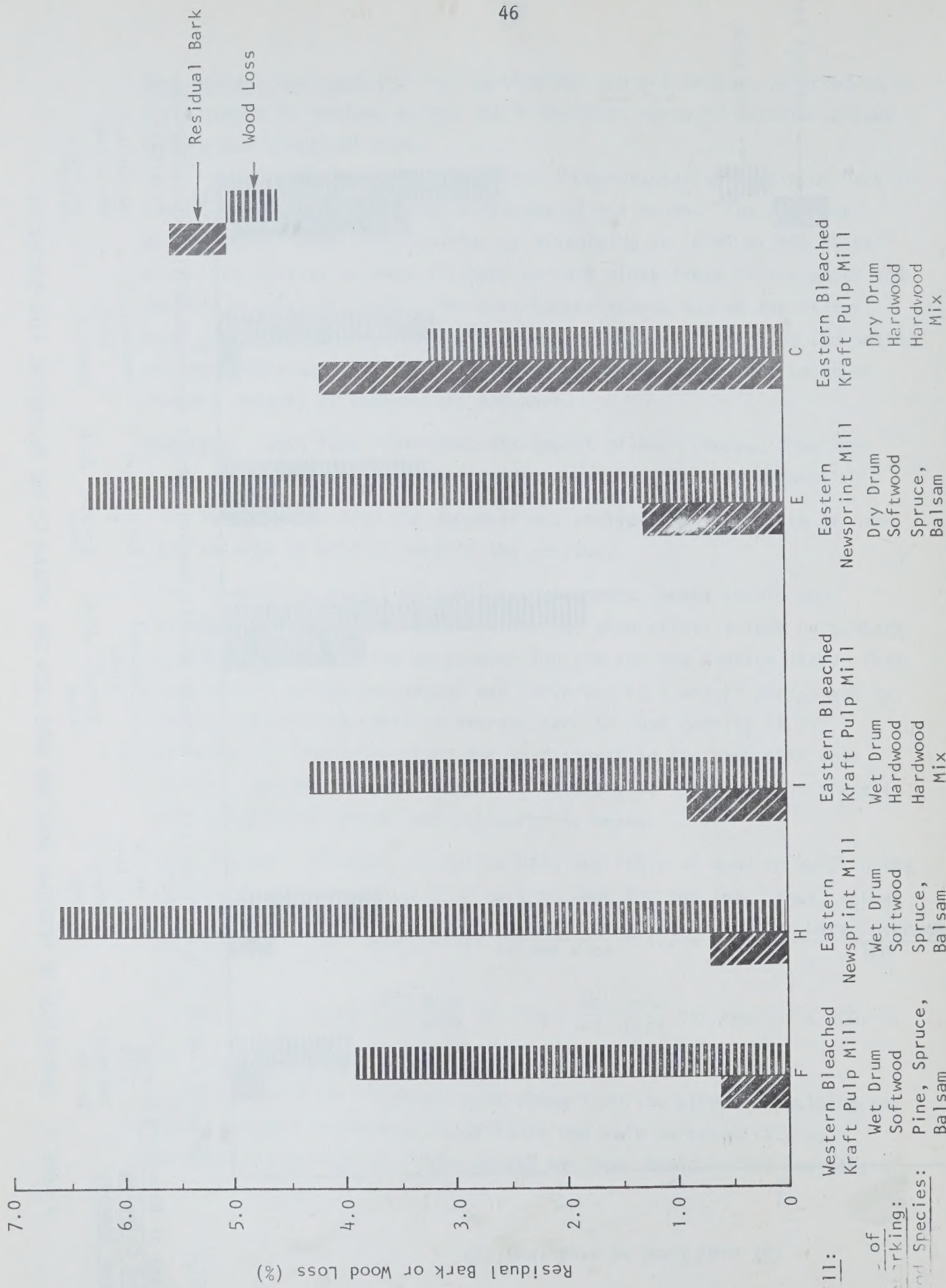


FIGURE 8. COMPARISON OF RESIDUAL BARK AND WOOD LOSS FOR WET AND DRY DRUM DEBARKERS

chips from various mill and debarking installations as illustrated in Figures 7 and 8. A summary of these data, including mean values, the 95% confidence intervals and the range of values, are included in Appendix 3. Because individual rather than composite samples were used, sample variability is relatively high as indicated by the confidence intervals and ranges.

While the results apply only to a limited number of mills, they provide an indication of what can be expected on a broader scale. The range of mean residual bark contents for the four debarking systems is summarized below and indicates the greater variability in mean values between mills with dry compared to wet debarking systems:

<u>Type of Debarking</u>	<u>Wood Species</u>	<u>Residual Bark Content (%)</u>
Hydraulic	Softwood	0.3 - 0.4
Mechanical Ring	Softwood	0.2 - 1.8
Wet Drums	Softwood & Hardwood	0.6 - 0.9
Dry Drums	Softwood & Hardwood	1.3 - 4.3

Some distinction should be made between debarking at sawmill and pulp mill installations. Sawmills generally receive higher quality logs and chip the slabs resulting from lumber manufacture, which represent about one-quarter of the log volume. Pulp mills, on the other hand, generally receive the lower quality irregular logs and chip the entire log. Thus, for similar debarking efficiency, sawmill chips should contain a higher percentage of residual bark.

It is instructive to group the data in order to compare residual bark contents for the following categories:

- wet and dry debarking,
- chips from sawmill slabs and pulp mill whole logs,
- softwood and hardwood.

This type of comparison has been drawn up in Table 17. Also included in the table are the results of a statistical comparison (t test) to determine the significance of the difference between mean values of residual bark. The comparison indicates that dry debarking is more sensitive than wet debarking to the quality of the log being debarked

TABLE 17. RESIDUAL BARK COMPARISON

Debarking	Type of Comparison		Mills Being Compared and Average Residual Bark (%)	Significant Difference at 95%
		Mill or Wood Type		
1. Hydraulic		Sawmill to Pulp Mill	G (0.3) to D-1 (0.4)	No
2. Mechanical		Sawmill to Pulp Mill	B (0.2) to D-2 (1.8)	Yes
3. Hydraulic to Mechanical		Sawmill	G (0.3) to B (0.2)	No
4. Hydraulic to Mechanical		Pulp Mill	D-1 (0.4) to D-2 (1.8)	Yes
5. Wet to Dry Drum		Softwood	F&H (0.7) to E (1.3)	No
6. Wet to Dry Drum		Hardwood	I (0.9) to C (4.2)	Yes
7. Wet Drum		Softwood to Hardwood	F&H (0.7) to I (0.9)	No
8. Dry Drum		Softwood to Hardwood	E (1.3) to C (4.2)	Yes

(sawmill log or pulp mill log) and the wood species (softwood or hardwood) as discussed below.

4.3.1 Hydraulic and mechanical ring

This comparison has focused on the relative efficiency of either system debarking sawmill logs and pulp mill logs. All of the comparisons are for coastal pulp mill and sawmill installations with similar wood species.

Comparisons 1 to 4 in Table 17 indicate that hydraulic and mechanical debarking operate similarly when debarking better quality sawmill logs; however, with the more irregular logs that the pulp mills are receiving, hydraulic debarking is superior. Also apparent is the higher percentage of bark in pulp mill chips after mechanical debarking despite the greater dilution available compared to slab chips from sawmills.

The above conclusions concur with the discussion in Section 3.4 for sulphite mills with wet and dry debarking. Other evidence for residual bark content with hydraulic and mechanical debarking is provided in the chip quality study by Hatton (1975). These data, summarized in Table 18, indicate the superiority of hydraulic debarking and the higher bark content of pulp mill chips compared to sawmill chips after mechanical debarking.

4.3.2 Wet and dry drum

All of the wet and dry drum installations considered were at pulp mills. These mills use dry transportation and storage methods and debark at similar rates. All of the wet drum installations use heated fresh or recycled process water. Neither of the dry drum installations had adopted pretreatment before debarking. The comparison of wet and dry drum debarking included installations with both softwood and hardwood debarking.

The data for softwood debarking at Mills F and H were grouped since they debark under the same conditions and no significant difference was detected between their means. Comparisons 5 to 8 in Table 17 indicate that wet and dry drum debarking operate similarly when debarking softwood. However, with hardwood, wet drum debarking is apparently superior. One would expect higher bark residuals with hardwood based on Berlyn's (September, 1965) measurement of the bark-to-wood bonding strengths. It

TABLE 18. YEARLY MEAN RESIDUAL BARK DATA* FROM WESTERN FOREST PRODUCTS LABORATORY CHIP-QUALITY STUDY

Mill	Type of Debarking and Chipping			
	Hydraulic Debarking		Mechanical Ring Debarking	
	Pulpwood Whole Log Chipping	Sawlog Slab Chipping	Pulpwood Whole Log Chipping	
M&B, Harmat (Integrated Kraft Pulp Mill and Sawmill)				
Wood Species	Cedar, Fir	Hemlock	Hemlock	
Residual Bark Percentage	0.2 ± 0.1**	1.3 ± 0.2	1.8 ± 0.6	
Northwood P&P (Integrated Kraft Pulp Mill and Sawmill)				50
Wood Species	No Hydraulic Debarking	Fir, Pine, Spruce	Fir, Pine, Spruce	
Residual Bark Percentage	--	0.5 ± 0.2	2.0 ± 0.5 (<8 in dia)	
			1.3 ± 0.4 (8 in - 16 in dia)	

* In all chip fractions except in chips and fines.

** 95% confidence interval.

appears that wet drum debarking is able to overcome the higher bonding strength of hardwood while dry drum debarking is not.

The results of this survey indicate an apparent, but not significant, difference between the wet and dry drum debarking of softwood, while the experience of Mills 1 and 2 discussed in Section 3.2 indicates that bark residuals increase in converting to dry debarking. The latter results are likely more valid; however, the results of this survey suggest that differences encountered with softwood may be site specific rather than industry wide.

Summarized in Table 19 are the ranges of average bark residuals obtained from this survey, from mill data reported in Section 3 and from Hatton's survey (1975). Based on these data, it would appear that dry drum and mechanical debarking at pulp mills would have difficulty consistently meeting the stringent residual bark requirements of sulphite and groundwood mills (less than 0.5%). Hydraulic debarking appears to be consistently able to meet this requirement while wet drum debarking is marginal. With kraft pulping, where the standards are generally somewhat more lenient, the main concern appears to be dry debarking of hardwood.

TABLE 19. AVERAGE SOFTWOOD BARK RESIDUALS OBTAINED FROM THIS SURVEY AND OTHER SOURCES

<u>Type of Debarking</u>	<u>Bark Residual</u> (%)
Hydraulic	0.1-0.4
Mechanical Ring	0.2-2.0
Wet Drum	0.4-0.7
Dry Drum	0.9-2.4

4.4 Wood Loss

Concern over wood loss is one of simple economics, that of maximizing the chip yield from purchased logs. Estimates of wood loss based on data from this survey are also summarized in Appendix 3 and illustrated in Figures 7 and 8. As with the chip analysis, wood loss data are intended to provide an overview in light of the lack of available mill and literature data. Mean values for wood loss range from 1.1% with

hydraulic debarking to 6.6% with drum debarking. Variability between samples tested for each mill was high as indicated by the confidence interval and the range.

Because of the large variability between samples, analysis of variance failed to detect a significant difference between any of the wood loss data at the 95% level of significance. In view of this, mean values for wood loss are summarized in Table 20 to provide a relative indication of losses that can be expected with wet and dry debarking. Any differences that are apparent in this table would need to be substantiated by a more in-depth sampling program.

Based on these data, it would appear that wood losses can be expected to be 1% to 2% with hydraulic debarking, 2% to 3% with mechanical debarking and 4% to 5% with drum debarking. While differences between mechanical and hydraulic debarking losses are apparent, differences between wet and dry drum debarking are not.

TABLE 20. AVERAGE VALUES OF WOOD LOSS FOR DIFFERENT TYPES OF DEBARKING

<u>Type of Debarking</u>	<u>Average Log Diameter</u>	<u>Average Wood Loss (%)</u>
West Coast Hydraulic	Softwood - 48 cm	1.3
West Coast Mechanical Ring	Softwood - 38 cm	2.3
Eastern Mechanical Ring	Softwood - 18 cm	2.6
Wet Drums	Softwood and Hardwood - 20 cm	4.9
Dry Drums	Softwood and Hardwood - 23 cm	4.8

One must also recognize that some difference in percentage wood loss can be attributed to a difference in log diameter; losses on a percentage basis decrease with increasing log size. One must bear this in mind when comparing wood losses from hydraulic debarkers processing larger logs to those from drum and mechanical debarkers processing logs one-third to one-half the diameter.

While there are little comparative data available from mills and in the literature, it is instructive to compare estimates of wood loss

obtained in this survey to other sources. This comparison is presented in Table 21 and discussed in more detail below. Values quoted range from 0.1 to 10% and there is little agreement among various sources.

One of the more in-depth studies of wood loss was made by Phillips (1976) where wood losses for a mechanical ring debarker and a Rosser head debarker were compared using Southern pine sawlogs. Losses for the mechanical ring debarker averaged 1.1% and averages for the Rosserhead ranged from 1.7 to 4.3%. Variations in wood loss were found to be mainly linked to equipment maintenance and operator skill. The effects of wood loss on timber yield, which are of doubtful significance based on observations made in this survey, are also discussed. Calvert and Garlicki (1974), using optimum debarker settings with no pretreatment, achieved an average wood loss of 1.5% for the mechanical ring debarking of frozen logs. Neill (1976) in his survey of hog fuel usage analyzed the quantity of wood and bark in the debarking residue from a northeastern United States pulp mill and the wood loss data summarized are based on his analysis. Ranhagen (1970) compared wood losses for different debarking methods and used a range of 0.5 to 3% for drum debarking and 3 to 10% for mechanical debarking.

With drum debarking, most of the wood loss information has been related to a comparison of parallel and tumbling drum debarking. Axel Johnson and Co. (1969), a supplier of parallel drum debarkers, stated that fibre loss by brooming in a tumbling drum debarker is 1% to 3%. With parallel drum debarking, they claim wood losses are less than 0.5% at 98.5% bark removal. Ranhagen (1971), also representing a supplier of parallel drum debarkers, quoted a total wood loss with wet tumbling drums of 3.3% compared to a loss of 1.5% with dry parallel drums. This difference is due to lower debarking losses and less pin chips and fines production. Dyck (1972) stated that the Great Lakes Paper Company, in converting to a system of dry parallel debarking, reduced wood losses by 3.5%.

Two pulp mills have provided wood loss estimates for their drum debarking systems based on analysis of their bark residue. One mill with wet and dry tumbling drum debarking estimated a wood loss of 7%, while another mill with dry tumbling drum debarking estimated its wood loss at 2%.

TABLE 21. SUMMARY OF WOOD LOSS DATA OBTAINED FROM THIS SURVEY AND OTHER SOURCES

<u>Source</u>	<u>Type of Debarking</u>	<u>Wood Loss Based on Dry Wood Weight (%)</u>
This Survey	Hydraulic	1.1-1.4
This Survey	Mechanical Ring	1.9-3.3
This Survey	Wet Drum	3.9-6.6
This Survey	Dry Drum	3.2-6.3
Phillips (1976)	Mechanical Ring	1.1
	Rosser Head	1.7-4.3
Calvert & Garlicki (1974)	Mechanical Ring (frozen logs)	1.5
Neill (1976)	Mechanical Ring	2.1 (summer)
		8.9 (winter)
	Drum	5.2 (winter)
Ranhagen (1970)	Mechanical Ring	3-10
	Drum	0.5-3
Axel Johnson & Co. (1969)	Tumbling Drum	1-3
	Parallel Drum	0.1
Ranhagen (1971)	Wet Drum	3.3
	Dry Parallel Drum	1.5
Horn & Auchter (1972)	General	5-10
Pulp Mills	Wet and Dry Drums	2-7

Some broad statements on wood loss have also been made by a few authors. Horn and Auchter (1972) used a wood loss of 5 to 10% as a basis for an economic justification for eliminating debarking. Edde and Sebbas-Bergstrom (1974) claimed that savings were achieved with dry compared to wet debarking because of lower wood losses.

While concern over wood loss is related to the loss in wood value, some credit must also be given to its energy value in hog fuel. The economics involved are discussed in Section 7.3. Another consideration for coastal pulp mills is that removal of the salt concentrated outer wood layer may help minimize liquor salt concentrations.

4.5 Salt and Hardness Content of Chips and Bark

Sodium chloride (salt) absorption into logs is responsible for the predominant input of chlorides to the pulping liquor system. Concern over chloride in pulping liquor stems from its possible effects on the operation of the recovery boiler in terms of liquor fuel value, liquor solids concentration, particulate discharge, and corrosion problems. Increased boiler and evaporator tube fouling and corrosion have been noted by Karjalainen et al (1972). Chloride and hardness ions in hog fuel are a concern for similar reasons: corrosion, boiler deposits and particulate emissions. Essentially no data have been identified on the effects of wet and dry debarking or the use of recycled mill effluents in wet debarking on the sodium chloride and hardness ion concentration of wood chips and hog fuel.

A detailed study by MacLean and MacDonald (1968) of the salt distribution in sea water transported logs, indicated that the salt content of the outer layers of sapwood averaged 1.4 to 3.1% based on oven dry wood. Half of this concentration was absorbed in the first three weeks, and after six months storage the salt concentration approached the maximum of 4 to 7% in the outer layer of wood. In the inner layers of heartwood, the salt concentration was trivial (0.01 - 0.05%). Thus, the average salt concentration in sawmill chips where the outer slabs are chipped will generally be higher than pulp mill chips where whole log chipping is practiced. Also the sawmill sawdust and shavings added to the hog fuel will be low in salt since a large percentage originate with the inner heartwood.

For this survey, composite samples of bark and chips were taken at coastal wet and dry debarking installations as well as inland installations with and without effluent recycle. The equivalent salt and hardness content of these samples was measured using the extraction procedures described in Section 4.2 and the results of these analyses are summarized in Table 22.

Calcium and magnesium ions extracted from the bark were expressed as equivalent hardness based on oven dry weight of bark. Equivalent hardness ranged from 1.24 to 3.68% but there was no apparent relationship between the type of storage and debarking and the equivalent hardness content of the bark.

All of the coastal installations stored their logs for similar time periods (two to four months) in water of 3.2% salt content. The concentration of salt in the chips from these mills ranged from 0.33 to 0.96% and is within the range 0.3 to 1.7% determined by Karjalainen et al (1972). The salt content of bark ranged from 0.57 to 1.69% or one and a half to three and a half times the salt concentration in chips.

The fact that debarking can have a substantial influence on salt content is well illustrated by installations D-2 and D-1 where logs of the same source are debarked by dry and wet means. The ratio of the salt concentrations in the bark and chips from the dry system (D-2) to that from the wet system (D-1) is about 3:1 and 1.5:1, respectively. The smaller differential in the chips is due to that fact that these are the result of whole log chipping. A greater difference would be noted for slab chips.

By comparing Mill B with Mill D-2, the higher salt content of slab chips compared with whole log chips is evident. The highest chip salt concentration was obtained with Mill G, where salt water is used in hydraulic debarking.

For mills that practice dry transportation and storage of their wood, salt concentrations were generally below the detectable limit of 0.025%. Exceptions to this are Mills H and I, where low salt concentrations have been detected. For Mill I, the source of chloride is bleach plant extract which is recycled to the woodroom. For Mill H, sources of chloride are either chlorides used for road de-icing or chlorination of debarking water to prevent slime accumulation.

TABLE 22. COMPARISON OF SALT AND HARDNESS CONTENT OF BARK AND CHIPS

<u>Mill</u>	<u>Wood Storage & Transport</u>	<u>Mode of Debarking</u>	<u>Mode of Chipping</u>	<u>Bark Analysis</u>		<u>Chip Analysis</u>	
				<u>Equiv. Hardness (% CaCO₃)</u>	<u>NaCl (%)</u>	<u>NaCl (%)</u>	<u>NaCl (%)</u>
B	Salt Water	Dry-Mech. Ring	Slab	1.24	1.69		0.74
D-2	Salt Water	Dry-Mech. Ring	Whole Log	1.59	1.63		0.48
D-1	Salt Water	Wet-Hydraulic	Whole Log	1.56	0.57		0.33
G	Salt Water	Wet-Hydraulic ¹	Slab	1.55	1.53		0.96
A-sm	Dry	Dry-Mech. Ring	Slab	1.43	ND ²		ND
A-lg	Dry ³	Dry-Mech. Ring	Slab	2.53	ND		ND
C	Dry	Dry-Drums	Whole Log	2.90	ND		ND
E	Dry	Dry-Drums	Whole Log	1.79	ND		ND
F	Dry	Wet-Drums	Whole Log	2.30	ND		ND
H	Dry	Wet-Drums	Whole Log	2.29	0.07		ND
I	Dry	Wet-Drums	Whole Log	3.68	0.18		ND

¹ Salt water used on debarker² Non-detectable (<0.025%)³ Logs passed through log pond before debarking

4.6 Bark Particulate Content

Dirt in hog fuel has been identified to be a major problem at mills from the point of view of erosion in bark handling systems and increased frequency of boiler cleanouts. As a result, dirt content can influence the acceptability or marketability of hog fuel, which is of particular importance to a sawmill or pulp mill faced with disposal problems. Methods taken to alleviate this problem, particularly where dry debarking and dry transportation and storage methods exist, are the use of log washers and the paving of dry land sorting areas.

The two variables which are considered to most influence bark dirt content are the type of storage (water or dry land) and the type of debarking (wet or dry). Water storage will generally remove much of the dirt accumulated in the woods. However, the effect of storage is seasonal. For example, in certain locations during spring runoff, river sand and silt may accumulate on the log. This imbedded sediment remains in the hog fuel after dry debarking, but is largely removed with wet debarking. Some mills with dry storage and dry debarking have a log pond or presteaming chamber for thawing the log surface prior to debarking. This can reduce bark dirt content as exemplified by Mill A in this survey.

Dirt content has been defined as bark particulate in this survey and represents the non-filterable, non-acid soluble residue in an ashed sample of bark. Results for the total ash and particulate content of the bark samples have been grouped according to the type of storage and type of debarking and summarized in Table 23.

These results indicate that the bark ash content ranged from 1.2 to 5.9% which is comparable to the range of 0.6 to 3.7% for western wood species established by Corder (1973). Particulate content ranged from 0.04 to 2.5% which represents between 2 and 60% of the total quantity of ash.

To compare the relative influence of the type of storage and debarking on bark particulate content, grouped data are presented in Figure 9. Although averages are based on limited information, the trend of values indicates that the type of debarking has considerably greater influence on bark particulate content than the type of storage. Bark particulate content from wet debarking is an order of magnitude smaller

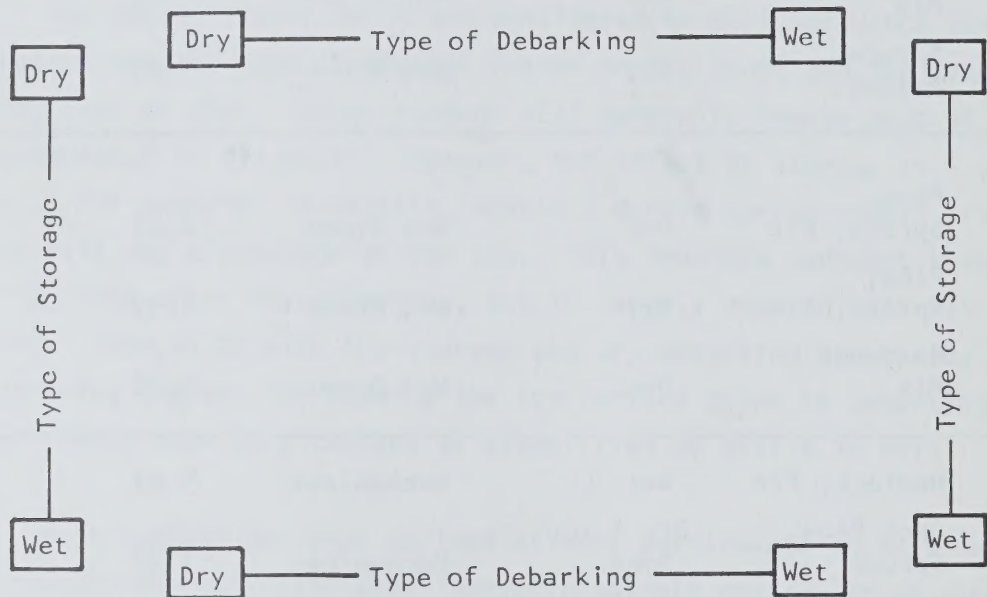
TABLE 23. ASH AND PARTICULATE CONTENT OF BARK SAMPLES

<u>Mill Code</u>	<u>Wood Species</u>	<u>Wood Storage and Transport</u>	<u>Type of Debarking</u>	<u>Ash Content* (%)</u>	<u>Particulate Content (%)</u>
A-sm	Jack Pine, Spruce	Dry	Mechanical	4.26	2.48
C	Hardwood Mix	Dry	Dry Drums	4.95	1.14
E	Spruce, Balsam	Dry	Dry Drums	1.69	0.04
F	Pine, Spruce, Fir	Dry	Wet Drums	2.27	0.26
H	Pine, Spruce, Fir	Dry	Wet Drums	1.99	0.10
I	Hardwood Mix	Dry	Wet Drums	3.58	0.14
B	Hemlock, Fir	Wet	Mechanical	5.92	1.49
A-1g	Jack Pine, Spruce	Dry + Log Pond	Mechanical	1.19	0.12
D-2	Hemlock, Balsam	Wet	Mechanical	4.22	0.36
D-1	Hemlock, Balsam	Wet	Hydraulic	1.89	0.06
G	Fir, Hemlock Balsam	Wet	Hydraulic	3.60	0.11

* Includes particulate

Average
Particulate = 1.22%

Average
Particulate = 0.17%



Average
Particulate = 0.66%

Average
Particulate = 0.09%

FIGURE 9. COMPARISON OF BARK PARTICULATE CONTENT ACCORDING TO THE TYPE OF STORAGE AND DEBARKING

than that from dry debarking, while the particulate content of water stored logs is about half that of dry stored logs.

The effects of debarking on particulate content are well illustrated by Mill D where the same source of logs is debarked by wet and dry means. An indication of the influence of log storage is provided by Mill A, where logs for the large log mill are stored in a log pond before debarking, and logs for the small log mill are debarked directly. Photographs illustrating the type and relative quantities of particulate for these as well as other mills are contained in Appendix 4.

4.7 Bark and Hog Fuel Moisture Content

Hog fuel moisture is undesirable for the following reasons:

- It directly influences heat content (Figure 10) and has a negative effect on boiler efficiency (Figure 11).
- Combustion of hog fuel with a high moisture content can significantly increase boiler emissions (Klicius and McCubbin, 1977).

Several factors influence the moisture content of hog fuel. These include type of log storage and type of debarking, as well as changes in hog moisture with storage and transport. Hog fuel may also be a conglomerate of many types of wood wastes. Neill (1976), in an extensive survey of Canadian hog fuel utilization, found that moisture content ranged from 30 to 65% with an average of 50 to 55%. Corder (1973) stated that the critical moisture content for combustion is between 64 and 70%, since above this a stable fire can no longer be maintained. Newby (1973) recommended keeping bark out of contact with water and concluded that justification may exist for changing from wet to dry debarking on this basis. Neill (1976) also recommended the use of dry debarking techniques to keep moisture levels low and stated that bark presses are economically justified in the case of wet debarking. A further reduction in moisture content can be obtained with a hog drying system, using combustion gas. Klicius and McCubbin (1977) evaluated the feasibility of hog fuel drying and found this to be economically unattractive at the present time.

A survey of mill installations indicated several approaches to minimizing hog fuel moisture. As discussed in Section 3, conversion to

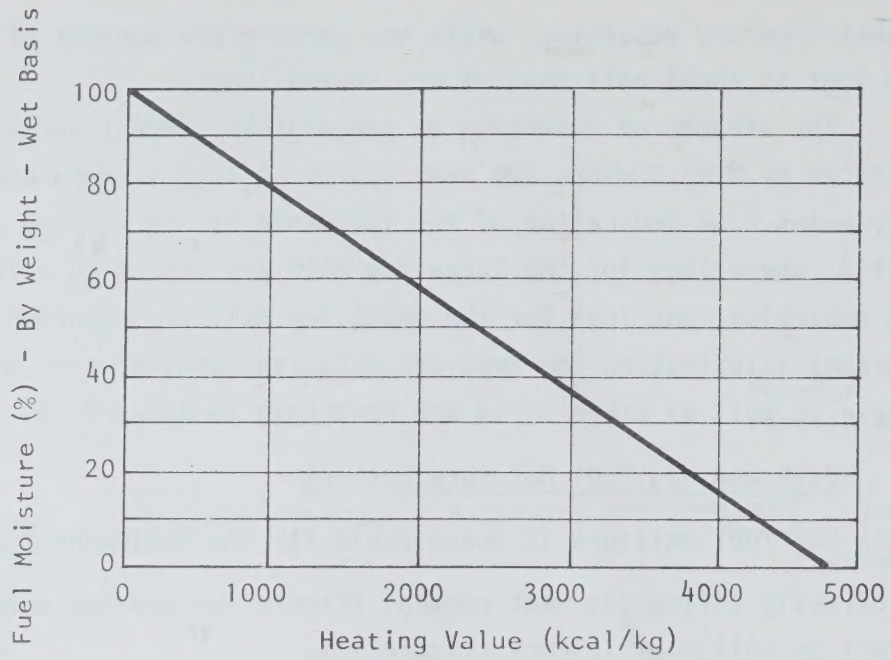


FIGURE 10. FUEL MOISTURE VERSUS HEATING VALUE
(After Neill, 1976)

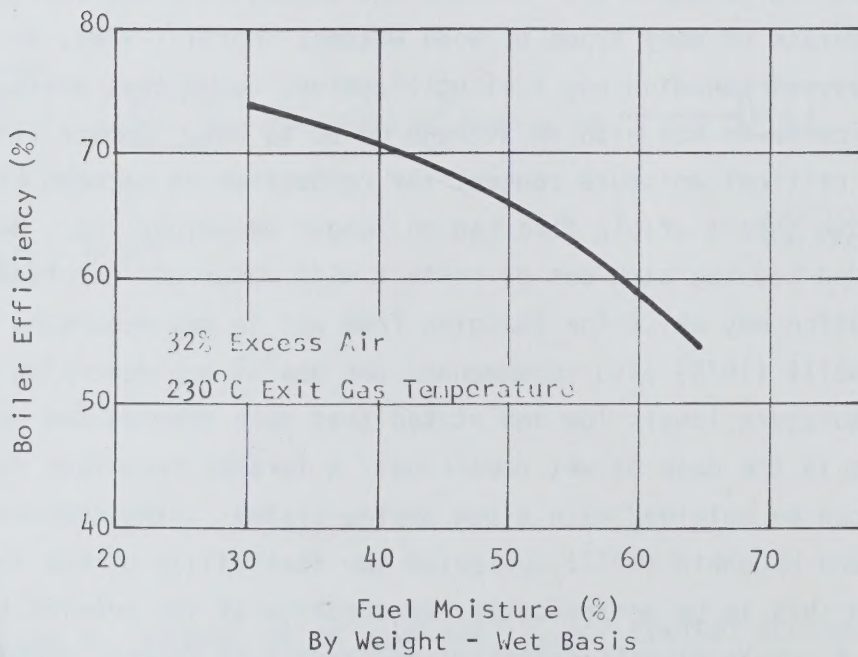


Figure 11. BOILER EFFICIENCY VERSUS HOG FUEL MOISTURE
(After Neill, 1976)

dry debarking generally decreased hog fuel moisture content and increased its utilization since bark presses were in some cases a bottleneck. Where wet debarking was practiced, bark presses were usually used. Another approach was to blend different hog sources of varying moisture content. This was particularly effective where low moisture sawmill waste was available or where a mill had both a wet and a dry debarking system in operation. Other mills pointed out that appreciable changes in hog fuel moisture could result from outside storage and open transport.

Where hog fuel is unacceptable, because of high moisture content or other reasons, it must be disposed. Besides the loss in energy value, there is also the cost of disposal and the possible leachate problem (Econotech, 1976). A small coastal sawmill estimated its disposal cost at \$1.40/m³ (\$4/cunit), while Mill 1 in Section 3.2 roughly estimated a figure of \$0.35/m³ (\$1/cunit) for disposal of half of its hog fuel. These costs can add significantly to the cost of debarking and wood handling.

Information in the literature on the comparison of hog fuel moisture from wet and dry debarking is somewhat sketchy. An indication of values encountered is summarized below. These data indicate that the hog fuel from dry debarking without pressing has approximately the same moisture content as pressed hog fuel from a wet debarking operation:

<u>Source</u>	<u>Hog Fuel Moisture (Wet Basis)</u>	
	<u>Wet Debarking (%)</u>	<u>Dry Debarking (%)</u>
Ranhagen (1971)	57 (after pressing)	60 (no press)
Hooper (1977)	55	46
Newby (1973)	55 (after pressing)	-
SSVL (1974)	-	55 - 60

Further information on the relative influence of log storage and debarking on hog fuel moisture was provided from mill data and the analysis of composite samples in this survey. This data is summarized in Table 24 and indicates the following:

- Results from the sample survey are in general agreement with the range of mill data encountered.

TABLE 24. HOG FUEL MOISTURE CONTENT BASED ON MILL AND SAMPLE DATA

Log Transport And Storage	Type of Debarking	Press Included	Hog Moisture from Mills*		Hog Moisture from Sample Survey**		
			Before Press (%)	After Press (%)	Mills Sampled	Before Press (%)	After Press (%)
Wet	Wet	Yes	65-70	55-60	G	65.6	58.0
Wet	Dry	No	55-60	--	B	59.1	--
Dry	Wet	Yes	60-65	50-55	F, H, I	--	56.5
Dry	Dry	No	45-50	--	A-sm, A-1g C, E	49.9	--

* Based on data obtained from various mill installations.

** Composite samples without appreciable wood residue.

- For water-stored logs, an average hog moisture of 55 to 60% can be expected from both wet debarking after pressing and from dry debarking without a press.
- For dry-stored logs, hog moisture from wet debarking is about 55% after pressing, compared to about 50% from dry debarking without a press.

Thus, in converting from wet to dry debarking, a bark press is eliminated and in the case of dry stored logs, a further reduction in moisture content is also achieved.

For sawmills, the effects of log storage and debarking on hog fuel moisture are less pronounced. Dobie and Wright's (1975) figures indicate that as much as two-thirds of the hog fuel produced can consist of sawdust and wood shavings with the remainder being bark. Since sawdust and shavings have a moisture content of 35 to 40%, the net moisture content of this sawmill waste would only vary from 40 to 50% even if the bark moisture ranged from 45 to 70%.

5. EFFLUENT CHARACTERISTICS

5.1 Variables Affecting Effluent Quality

The nature of the effluent produced by wet debarkers depends on several variables including: debarker type, wood species, climate, season of wood harvest, method of log transport, time and conditions of log storage, and source and quantity of water used.

The two principal types of wet debarkers are wet drum and hydraulic. Wet drum debarkers are the most prolific and are used extensively in the eastern United States and eastern Canada. A description of these debarkers is presented in Section 2.2. Water is sprayed on the logs as they enter the drum, reducing the strength of the bark-to-wood bond. In cold climates, where most wet drum debarkers are employed, hot fresh water or various mill effluents are usually used in the winter to thaw the logs and facilitate bark removal. Also, the logs are often sprayed prior to entering the drum to wash off silt and sand and after the drum to wash off loosened bark. Flume water, used for transporting the logs to the debarker, is often part of a wet drum operation; this water is usually recirculated after screening. The wet drum normally produces higher effluent pollutant loadings than hydraulic debarkers because of the longer wood-to-water contact time and the greater amount of friction experienced by the logs.

Hydraulic debarkers and their operation are also discussed in Section 2.2. In North America the hydraulic debarker is found almost exclusively on the west coast, mainly to process large diameter logs and cedar, which is difficult to mechanically debark because of its stringy bark and flared butts. Water usage is higher than that of wet drums, producing higher effluent rates per unit of wood processed but, generally, less of a pollutant load because the bark and wood is less broken up.

5.1.1 Wood species

The species of wood debarked affects the effluent due to differing chemical constituents and particle size for different barks, and the varying difficulty of bark removal. Each species of bark has a wide variety of extractives which are often different or present in

differing quantities than other species. A study by Econotech (1976) of Douglas fir and cedar bark leachates determined that the Douglas fir bark produced higher BOD_5 , toxicity, and colour, and a lower pH. Also, softwoods (especially spruce, balsam, and Jack pine) have a higher pitch content than hardwoods, which potentially results in increased pitch blinding of effluent screening and other equipment, which adversely affects treatment efficiency. Species type also affect the particle size of the effluent suspended solids; cedar bark, for example, will yield long fibres relative to other barks. The difficulty of debarking will vary from species to species which in turn will determine the amount of water required and hence the effluent volume. One mill employing wet drum debarkers reported that the debarking rate of water-drive Jack pine was about twice that for water-driven spruce. Furthermore, it was noted that bark was more readily removed from large diameter logs than from small logs (Boegh, 1969). Another mill, wet drum debarking hardwoods, reported that of poplar, maple, and birch, poplar was much more difficult to debark. The wood species, therefore, can affect the amount of water per unit of wood required for debarking and accounts to some extent for the variance in effluent rates at different installations.

5.1.2 Climate and season

Climate also affects the nature of the effluent. In cold winter climates hot water is often used prior to debarking to thaw the logs and facilitate bark removal. This water is often applied by showers at the entrance to the debarker. Many wet drum operations associated with pulp and paper mills increase the use of mill white water or other hot mill effluent to the drum sprays during the winter for the additional heat input; this can substantially affect the debarker effluent characteristics. Most hydraulic debarkers, however, are located on the west coast where the milder climate and more consistent wood conditions do not require this sort of treatment.

The season in which the wood is harvested can affect the debarkability, as discussed in Section 2.3, and therefore the effluent. The increased difficulty in bark removal from winter cut wood tends to increase the water usage per unit of wood processed by reducing the wood throughput.

5.1.3 Log transport and storage

The method of log transport (i.e. by land, water, or combination of the two) affects several effluent parameters. For example, if transport has been by water much of the dirt will have been washed from the logs, resulting in less wear of wood handling and effluent treatment equipment, and some of the extractives will have been leached from the bark, thereby reducing the BOD_5 and probably the colour and toxicity of the debarker effluent. Kronis and Holder (1968) noted that for water driven wood, pitch in the debarker effluent was reduced, or at least a reduced problem with regard to treatment equipment, speculating that much of it was probably extracted during transport. Also, less water usage per unit of wood will be needed as some bark will have been removed during water transport (as much as 50% is common) and also the wet wood is more easily debarked because of the reduced strength of the bark-to-wood bond. Water driven wood, therefore, should be easier to debark than land transported wood producing less effluent of better quality.

The time and conditions (wet or dry) of log storage may also affect the effluent quality. Wood stored under dry conditions is generally more difficult to debark than wet stored wood, requiring more water for debarking and resulting in an increased effluent rate. Also, water stored wood will have a quantity of the organic extractives solubilized in the water resulting in a reduced organic load in the debarker effluent.

5.1.4 Makeup water

The source of makeup water to the debarker will have a substantial effect on the effluent quality. For example wet drum installations associated with pulp and paper mill complexes (which most of them are) often use other mill effluents such as white water or bleach plant alkaline effluent for some of the makeup; naturally these effluents provide an additional pollutant load to the debarker effluent. Hydraulic debarkers, however, almost always use fresh water because of the erosion problems on the high pressure pump and nozzles if water containing high suspended solids is used.

5.1.5 Bark pressate

Another factor that affects the quality of the debarking effluent as well as its treatability is whether bark pressate is included. Some debarker installations do not have to deal with bark press effluent either because the bark is landfilled or transported elsewhere for dewatering, or because the pressate is discharged elsewhere for treatment. The bark press effluent contains a higher concentration of soluble wood extractives than the rest of the debarker effluent and much of the pitch. One mill determined that almost all the pitch that accumulated on the effluent screens was contributed by the bark press effluent and concluded that a better approach would have been to treat the bark press effluent separately (O'Brian, 1968).

Because of the large number of variables affecting effluent flow rates and pollutant concentrations and loadings there is a wide range of these parameters, and it is apparent that each installation is unique. The following sections discuss the specific effluent parameters in more detail.

5.2 Effluent Volume

The effluent volume from both wet drum and hydraulic debarkers can vary considerably depending on a number of factors as discussed in Section 5.1.

A study (NSCI, 1966) of United States hydraulic debarker installations found that effluent rates of 3400 to 4500 l/min (900 to 1200 US gpm) were normal with a maximum rate of 9500 l/min (2500 US gpm).

A survey (Envirocon, 1976) of Canadian debarking installations found that the water usage for five wet drum and five hydraulic debarkers averaged 2270 and 4010 l/m³ (1700 and 3000 US gal/cunit) of wood debarked, respectively, with ranges of 1250 to 3820 l/m³ and 1950 to 6260 l/m³. Although wet drum debarkers inherently use less water than hydraulic debarkers, some of the difference was attributed to the effluent recycling practices at some of the drum debarker installations. Ten of the hydraulic debarker installations contacted in the course of this study reported water usages of 2000 to 7100 l/m³ of wood debarked. Five wet drum operations reported effluent rates of 1000 to 4500 l/m³, all of which practice effluent recycle to some extent.

So-called dry drum debarkers often have some effluent as the result of wash, thawing, or flume water. Such a northern Ontario mill had an effluent rate varying from 190 - 1890 l/min (50 - 500 US gpm). A report (Swedish Steam User's Association, 1974) on Swedish pulp mills recorded dry drum debarker water usages of 0 - 5000 l/tonne of pulp.

The above data demonstrate that, in general, hydraulic debarkers use more water per volume of wood processed than wet drum debarkers and emphasizes the variability of wet debarker effluent rates.

5.3 Total Suspended Solids

Total suspended solids (TSS), or non-filterable residue, is the effluent parameter of primary concern for wet debarker effluents. Most wet debarker effluent treatment equipment installed to date has had the single purpose of reducing suspended solids. The major portion of the suspended solids from a wet debarking operation is settleable and if not removed prior to discharge will settle out in the receiving water. This mostly organic sludge layer will exert an oxygen demand as it decomposes, reducing the available oxygen to fish and other organisms. In the extreme, the decomposition process will release toxic hydrogen sulphide. Also, the physical presence of the deposit will interfere with fish spawning and the bottom habitat in general. At the same time the nonsettleable fraction will increase the turbidity of the water, which reduces light penetration thereby impairing the photosynthesis of aquatic plants. The nature of these suspended solids, which consist mostly of bark fines, can be further defined by determining the fraction that is settleable, floatable, and volatile, and the particle size distribution.

An EPA survey (Glasser and Reed, 1974) of eight hydraulic debarker effluents after fine screening found TSS levels ranging from 521 to 2362 mg/l of which 41 to 180 mg/l were non-settleable; about 92%, therefore, were settleable. A survey (NCSI, 1966) of five U.S. hydraulic debarker effluents found that 93 to 97% of the settleable solids and 81 to 91% of the TSS can be removed by sedimentation. The settleability of the suspended solids will be affected by the presence of entrained air and at least one mill has installed deaeration equipment ahead of sedimentation facilities to reduce this problem. In general, however, the floatable

solids fraction (referring to the naturally floating solids and not to those solids that can be floated by aeration, which may be quite high as discussed in Section 6.2.3) of the suspended solids is quite low. The ash (non-volatile solids) fraction of the settleable solids can vary from 10 to 50% depending on the amount of silt and sand on the incoming logs.

The suspended solids loading for wet drum debarkers was reported (U.S. EPA, 1973) to range between 15 to 50 kg/tonne (30 and 100 lb/ton) of wood debarked which would be in the range of 5 to 40 kg/m³ depending on species and moisture content. A survey (Envirocon, 1976) of eleven Canadian mills, six with wet drum and five with hydraulic debarkers, indicated that the effluent suspended solids loadings was greater from the wet drum debarkers; the difference in particle size distribution, however, was insignificant (it might be expected that drum debarker effluent would have a higher percentage of small particles because of the increased friction in the wet drum process). The suspended solids loading ranged between 1.1 and 9.6 kg/m³ (7 and 60 lb/cunit) of wood debarked and between 0.48 and 3.5 kg/m³ (3 and 22 lb/cunit) for wet drum and hydraulic debarker effluent, respectively. The particle size distribution was approximately 35% > 50 mesh, 10% > 100, 200 and 400 mesh, respectively, and 35% < 400 mesh for both types of debarkers; particle size was not correlated to wood species. However, for one mill that wet drum debarks both softwood and hardwood, particle size analysis indicated that the distribution was essentially the same for both wood types. An eastern Canadian wet drum installation processing spruce and balsam reported (Tremblay and Samson, 1969) a particle size distribution of 47.5% > 14 mesh, 13.5% > 28 mesh, 8.0% > 48 mesh, 6.9% > 100 mesh, 4.8% > 200 mesh, and 19.3% < 200 mesh. Another wet drum installation (Ottersen et al., 1969) processing pine and spruce and using paper mill white water and bleach plant effluent for water makeup had the following particle size distribution for the bark drainer accepts: 27% > 12 mesh, 29.5% < 12 mesh and > 100 mesh, and 44% < 100 mesh. A mill with a drum debarker and using 50 mg/l suspended solids white water for makeup reported the following particle distribution: 12.9% > 14 mesh, 41.9% < 14 mesh and > 200 mesh, and 45.2% < 200 mesh. It is apparent that particle

size distribution varies considerably especially for wet drum installations due to the different mill effluent and quantities used for makeup. However, in general it can be concluded that a significant proportion of the suspended solids is very small.

The nature of effluent total suspended solids from wet debarkers can be summarized as follows: a major portion are settleable; the non-volatile fraction will vary depending on method of log transport and storage; the floatable fraction is usually small; the loading per unit of wood debarked is generally greater from wet drum debarkers than hydraulic debarkers; and the particle size distribution is quite variable but there is usually a significant fraction that is very fine (< 200 mesh) especially for drum debarkers where other mill effluents are often used for makeup.

5.4 Biochemical Oxygen Demand

The biochemical oxygen demand (usually determined by a five-day test and referred to as BOD_5) is an important effluent parameter that indicates the oxygen demand of bacteria as they metabolize the organics in an effluent. High levels of biodegradable organics in the effluent result in an increased oxygen demand which may produce depressed levels of oxygen in the receiving waters.

The BOD_5 in the effluent from a wet debarking operation is derived from the water soluble organics (or extractives) in the bark. The bark, like the wood, consists of cellulose, hemicelluloses, and lignin, as well as extractive substances. Cellulose and hemicelluloses are insoluble in water while a small fraction of the lignin is soluble. The extractives are generally soluble in water and include acids, carbohydrates, alcohols, tannins, and terpenes among other compounds.

Eight hydraulic debarker effluents surveyed by the EPA (Glasser and Reed, 1974) showed BOD_5 concentrations after fine screening ranging from 56 to 250 mg/l. Another source (NCSI, 1966) reported BOD_5 concentrations for several hydraulic debarker effluents of 60 to 120 mg/l.

In this study effluent BOD_5 concentration at a Canadian mill drum debarking softwoods (pine, spruce, and fir) without effluent recycle ranged from 412 to 1860 mg/l to 1 to 4 kg/m³ of wood debarked. The wide

range was attributed to the variability in log size and age, condition of the bark, intensity of debarking, moisture content of the bark, and the irregular rate of log processing. The U.S. EPA (1973) reported BOD₅ loadings from wet drum debarkers to be in the range of 7 to 10 kg/tonne of wood processed (15 to 20 lb/ton), or about 4 to 8 kg/m³ depending on species and moisture content. A recent study (B.C. Research, 1976) concluded that the BOD₅ of effluents from hardwood debarking was greater than that from softwoods. Samples taken at an Ontario mill wet drum debarking Jack pine, poplar, and dense hardwood (maple, birch, elm, ash) had the following BOD₅ loadings in kg/tonne (lb/ton) of wood debarked: 0.6-2.0 (1.15-3.98), 2.6-5.1 (5.22-10.19), and 1.0-4.5 (2.0-9.02), respectively. This contradicts the results of a study by Sproul and Sharpe (1968) of bark leachates from northeastern U.S. tree species which indicated that softwood bark produced a higher BOD₅ than hardwood bark.

Hydraulic debarking installations contacted during this study had BOD₅ loadings in the range of 0.2 to 1.0 kg/m³ of wood processed and concentrations of approximately 50 to 400 mg/l. Little data were available on BOD₅ for wet drum effluents but loadings as high as 3 kg/m³ and concentrations up to 2000 mg/l were reported; as with other pollutants in wet drum debarker effluents, the BOD₅ is affected by the source of make-up water and the extent of recycle.

Chemical characterization of log pond waters, which will have similar properties to the effluent from a wet debarker, containing Douglas fir and Ponderosa pine showed that the BOD₅:COD ratio was relatively low at 0.1 to 0.45, indicating that only a small percentage of the soluble organics were biodegradable (Schaumburg, 1973). This implies that biological treatment will not significantly reduce the soluble organics content of the effluent.

In general it can be concluded that the effluent BOD₅ concentration and loading per unit of wood debarked will be less for hydraulic debarkers than wet drum debarkers due to the higher water usages, greater use of fresh water, and less friction and residence time of the wood in the debarker.

5.5 Other Parameters

Although suspended solids and BOD₅ have been the effluent parameters of primary consideration, other pollutants such as toxicity

and colour are acquiring increased attention by regulatory agencies, and technologies for their reduction are rapidly being developed.

5.5.1 Toxicity

The toxicity of effluents from wet debarkers processing softwoods has been attributed to soluble wood extractives, especially resin acids (B.C. Research, 1976). Several samples from softwood debarkers resulted in 96 hour LC_{50} 's of usually less than 10% by volume (% v/v). No correlation could be derived for toxicity and BOD_5 . The toxicity of effluents from the debarking of hardwoods was less than that for softwoods, with LC_{50} values generally greater than 10%; this was attributed to the lower levels of resin acids. Effluent resin acid levels for a wet drum debarker processing pine, spruce, and fir ranged from 13 to 121 mg/l or 0.017 to 0.15 kg/m³ (0.09 to 0.81 lb/cord) of wood debarked. This range in resin acid levels could not be correlated with the wood species. One mill drum debarking Jack pine and hardwood produced effluent resin acid loadings of 0.02 to 0.2 kg/tonne (0.04 to 0.4 lb/ton) of wood debarked and < 0.01 to 0.03 kg/tonne (< 0.01 to 0.06 lb/ton), respectively.

It can be concluded from these data that debarker (hydraulic or wet drum) effluents are relatively toxic and that softwoods produce higher toxicity effluents than hardwoods.

5.5.2 Colour

The colour in pulp mill effluents has been attributed to the lignin and lignin derivatives from the wood (Swanson, 1973). Schaumberg (1973), in analyzing Douglas fir and Ponderosa pine bark leachates, found that most of the colour was due to lignins as well as tannins. The impact of colour on the receiving water is more than aesthetic as it reduces light transmittance, which adversely affects photosynthesis and therefore impairs the growth of phytoplankton and other aquatic plants.

There are little data available on the colour of debarker effluents. Sproul and Sharpe (1968) studied bark leachates from northeastern U.S. tree species and concluded that softwood bark produced a lower colour than hardwood bark. An EPA survey (Glasser and Reed, 1974) of eight hydraulic debarker effluents indicated colour levels of less than 50 colour

units. However, observations of hydraulic debarker effluents from mills visited during this project and results from a few samples indicated colour levels higher than this, up to 500 colour units. One wet drum debarker processing lodgepole pine reported an average colour level from three samples of 1200 colour units.

An interesting observation made during one study (Cambrian, 1976) was that oxidation of debarker effluent resulted in an increase of colour due to the oxidation and consequent agglomeration of colloidal particles; the colour was dramatically reduced upon removal of these newly formed particles by settling.

5.5.3 pH

Debarking effluents are slightly acidic due to the organic acids in the extractives, but can be significantly reduced by extensive effluent recycling. A wet drum debarker processing softwood (pine, spruce, fir) without effluent recycle had pH's varying between 5.2 and 7.0; another mill processing softwoods in a drum debarker and pH's of 3.7 - 4.3 for Jack pine, 4.0 - 4.8 for poplar, and 4.4 - 4.9 for dense hardwoods (B.C. Research, 1976). Although B.C. Research concluded that the pH results were probably about one unit low due to the time delay between sampling and testing it does indicate that the effluent pH of softwood effluents will probably be less than that for hardwoods. Hydraulic debarker installations contacted during this project reported pH's ranging from 5.5 to 7.2; wet drum installations were generally within this range also.

5.5.4 Slime

Slime, although not a direct effluent characteristic, often develops as a result of specific effluent parameters such as pH, temperature, and nutrient content. Slime build-up has been found to be a problem at many wet debarker effluent treatment installations due to plugging of equipment, especially screens.

5.5.5 Pitch

Pitch is a major problem in many debarker effluent treatment systems especially with respect to plugging of equipment, in particular screens used for bark fines removal. Pitch accumulation is worse when

debarking softwoods and eastern Canadian mills processing Jack pine experience the most extensive problems; also, fresh wood usually has a higher pitch content than old wood and therefore results in greater pitch plugging.

5.6 Relation to Total Mill Effluent

Where wet debarkers are associated with sawmills the debarker effluent is the source of almost all pollutants and most of the flow; other effluents that are relatively clean, such as cooling water, may also be included.

For wet debarkers associated with pulp mills the debarker effluent is generally a relatively small source of pollutants and effluent volume, although this is highly variable depending on debarker type, mill type, proportion of debarking done wet, and mill age and operation. Approximate ranges of effluent volume and pollutant parameters due to the debarker in relation to the pulp mill effluent are: flow, 5 to 15%; suspended solids, 10 to 25%; and BOD_5 , 3 to 10%. Generally, the higher end of the volume range and the lower values of the suspended solids and BOD_5 ranges apply to hydraulic debarkers and the opposite range limits to wet drums. The loadings of wet drum effluents especially, will vary considerably depending on makeup water source and volume; for example, one pulp and paper mill employing wet debarking reported that up to 50% of the discharged suspended solids was due to the woodroom effluent. The toxicity of wet debarker effluent is generally in the same range as that of a total bleached kraft mill effluent and therefore does not greatly affect the toxicity of the total effluent, although it does contribute to the overall toxicant load.

6. EFFLUENT TREATMENT

6.1 Government Regulations

This section summarizes government regulations for wet debarker effluents. Some of these regulations are actually "guidelines" or "objectives" which have site variations for compliance time and pollutant limits and are not applied universally within the designated jurisdiction.

In some provinces, principally those whose waterways do not contain anadromous fish, the administration of the regulations under the Federal Fisheries Act has been delegated to the province. Furthermore some provinces, notably B.C. and Quebec, the major forested provinces, have developed provincial objectives or guidelines for the industry.

There is some overlapping of jurisdiction, therefore, but it is widely accepted that in those instances where both federal and provincial regulations are relevant, the most stringent of the two should apply. Broadly speaking, however, the intent of environmental legislation of the various levels of senior government is similar and a conflict seldom occurs.

6.1.1 Canadian federal

The "Pulp and Paper Effluent Regulations, November, 1971" have, as component process categories, maximum loadings of total suspended solids for both hydraulic and wet drum debarking effluents which are 5.0 and 10.0 (9.0 for new mills) lb/0.D. ton of wood processed (not including bark), respectively; assuming 24 0.D. lb of wood/ft³ of green wood this is equivalent to 1.0 and 2.0 kg/m³ (6.0 and 12.0 lb/cunit). Another 5.0 lb/0.D. ton of suspended solids is permitted where "wood rewashing" is performed prior to utilization of the logs in the mill. These values are not regulations as such but factors used in calculating the permissible total mill effluent loading. In other words, the wet debarker effluent in a mill complex could be consistently higher than this value but the complex still meet its permitted total loading by other effluent loadings being consistently below their designated category loading. These values, however, are essentially regulations in cases where the debarker effluent is discharged separately. Permitted levels for BOD₅ are not specified for separate process categories but only

as a total for pulp mill type. The toxicity requirement for pulp and paper mill installations is 80 percent fish survival in 65 percent effluent using a continuous 96-hour bioassay.

There are presently no federal effluent regulations for sawmills.

6.1.2 British Columbia

The draft B.C. "Pollution Control Objectives for the Forest Products Industry" (1977) include specific objectives for hydraulic debarker effluents (there are no wet drum debarkers in B.C.). The objectives, which are merely guidelines used during deliberation of the pollution control permit (the legal document), include limits for total suspended solids, BOD₅, pH, and toxicity, and are shown in Table 25. Level A is the "desirable goal for all discharges and will generally apply to all new discharges and to existing installations whose discharges are significantly altered..." Level B objectives are to be met by all existing discharges within a specific time which is determined on an individual basis. As most hydraulic debarkers associated with pulp mills discharge process water to the mill effluent treatment facilities, these objectives apply mainly to sawmills. The toxicity objectives are based on a static bioassay compared to the continuous bioassay of the federal regulations.

The two different methods are not easily compared although Walden et al. (1975) attempted to do so; they concluded that the federal regulation, as described in the previous section, is more restrictive than a 96-hour LC₅₀ of 90% (50% survival in 90% effluent) using a static bioassay.

6.1.3 Quebec

The Quebec Ministry of the Environment, under the Environmental Quality Act, in December, 1975 issued draft regulations for pulp and paper mill effluents. The regulations are effective December 31, 1978. The proposed limits for non-filterable residue (total suspended solids) for hydraulic and wet drum debarking are 1.5 and 6.5 kg/absolute dry tonne of debarked wood, respectively, and for BOD₅ are 2.0 and 3.5 kg/absolute dry tonne, respectively. The proposed pH limits for pulp and paper mills are 5.5 and 9.5.

TABLE 25. DRAFT* B.C. EFFLUENT QUALITY OBJECTIVES FOR HYDRAULIC DEBARKERS

<u>Parameter</u>	<u>Units</u>	<u>Level A</u>	<u>Level B</u>	<u>Suggested Monitoring Frequency</u>
Total Suspended Solids	kg/m ³ (lb/cunit)	0.24 (1.5)	0.64 (4.0)	Daily composite 3 times per week
BOD ₅	kg/m ³ (lb/cunit)	0.18 (1.1)	0.64 (4.0)	Daily composite once per week
pH range ¹		6.5-8.0	6.5-8.0	Continuous
Toxicity ²	% effluent volume	100%	30%	Quarterly ³

1. Applicable only to fresh waters. Where background pH of receiving water is outside the designated range effluent pH shall not differ from background by more than ± 0.2 pH units.

2. 96-hour LC₅₀ static bioassay on salmonid species giving 50% survival over 96 hours. Tabled values are effluent dilutions (by volume) in which tests are to be conducted. For marine discharges, toxicity tests are to be carried out on neutralized samples.

3. If failure detected, frequency to be every two weeks until objectives met.

* At the time of writing, these draft objectives were not formally approved as policy.

6.1.4 United States federal

In the U.S. the Environmental Protection Agency in a development document issued in January, 1976 specified effluent requirements for the pulp, paper and paper-board industry (U.S. EPA, 1976). For the "Best Practicable Control Technology Currently Available" (BPCTCA) category the effluent limitations were to be met by July 1, 1977. Mills with wet woodyard operations are allowed additional BOD_5 and TSS loadings to their total mill effluent of 0.5 and 0.75 kg/tonne of air-dried pulp, respectively. Wet woodyards are defined as any or all of the following: log ponds used for defreezing logs; log transport and defreeze flumes; log washing; and wet debarking. The pH limits are 5.0 to 9.0. There are no regulations for toxicity ("... tests for toxicity are quite expensive, complicated, and subject to many variables and toxicity of pulp mill wastes can be reduced to acceptable levels with appropriate reductions of $BOD...$ ").

The EPA has also issued guidelines for the timber products industry as reported by Glasser and Reed (1974) which covered effluents from sawmills. There are two sets of effluent limitations for hydraulic debarking, the maximum for any one day and the maximum average of daily values for any period of 30 consecutive days. The maximum permitted BOD_5 and TSS values for any one day are 1.5 and 6.9 kg/m³ (9.3 and 43.0 lb/cunit) of product, respectively, and the maximum averages of 30 consecutive days are 0.5 and 2.3 kg/m³ (3.1 and 14.3 lb/cunit), respectively. The pH limit is 6.0 - 9.0. These limits are intended to fulfill the requirements of the Water Pollution Control Act of 1972 for BPCTCA. Furthermore, the effluent limits to be met by July 1, 1983 are to be based on the "Best Available Technology Economically Achievable" (BATEA), which for wet debarking is no discharge. Apparently EPA'S feeling was not that there would not be any hydraulic debarking by 1983 but that the treatment technology would be such that zero discharge would be achievable by total recycle of effluent. However, by 1983 it is expected that the percentage of large diameter logs, which is one of the main reasons for hydraulic debarking, will be considerably reduced therefore reducing the need for hydraulic debarking.

6.2 Treatment Methods and Effectiveness

To date, the primary purpose of treatment equipment on wet debarker effluents has been to remove the suspended bark fines. This is accomplished by a variety of equipment types and makes, but predominantly by screens. Various types of screening devices that are used or could be used for this purpose are discussed as well as other methods of suspended solids removal such as sedimentation, flotation, centrifugal separation, and filtration. As future regulations may require reduction of colour and toxicity, methods to reduce these pollutants are also briefly discussed.

6.2.1 Screening

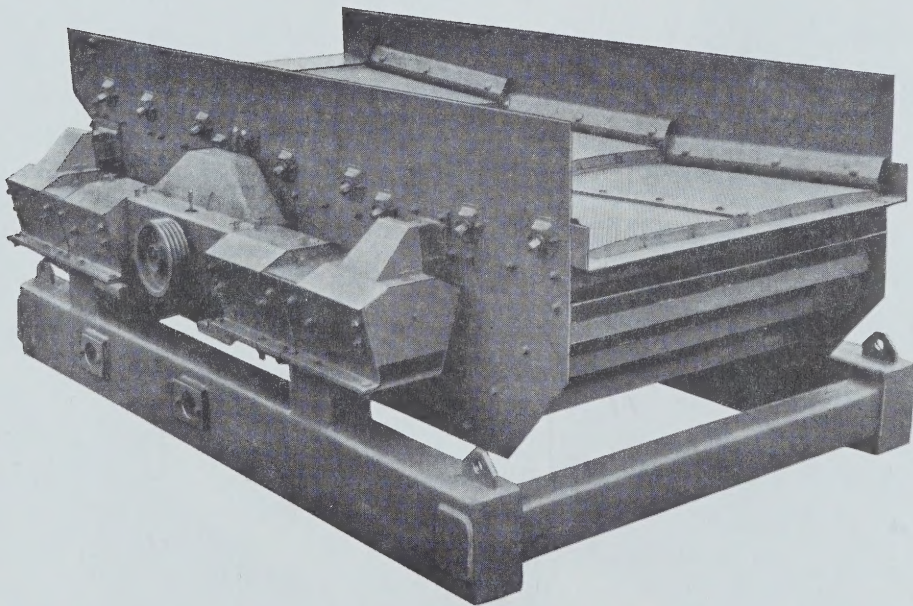
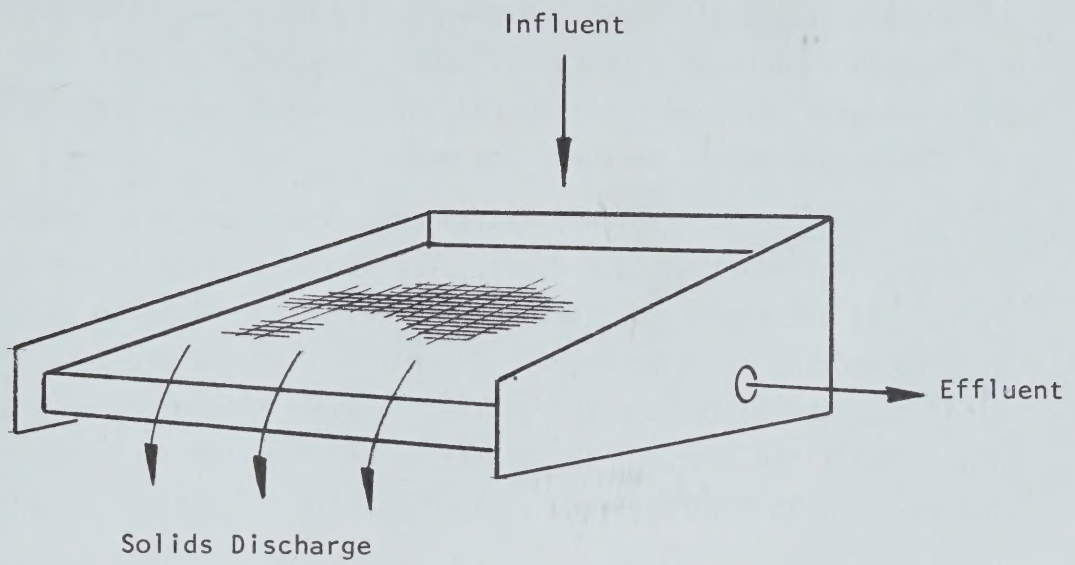
Coarse screening is generally the first step in the treatment of wet debarker effluents, the purpose of which is to remove large pieces of bark. This process is usually accomplished with rotary drainers, or in some cases by perforated drag conveyors. The rotary drainer is a rotating horizontal steel plate cylinder perforated with 6 to 12 mm (0.25 to 0.50 in) holes. The bark and effluent are fed in one end, the water and smaller bark particles pass through the holes, and the bark discharge at the other end. The bark is then conveyed to a bark press prior to use as hog fuel or stored before being landfilled.

Fine screens are usually employed after the coarse screening to remove some of the suspended bark fines. The screen mesh sizes vary widely depending on manufacturer and effluent characteristics, but usually have openings in the range of 0.15 to 2.0 mm (100 to 9 mesh). These screens are generally of two main types: vibrating horizontal or inclined stationary. Other screen types have been piloted or used full-scale and some of these are also discussed.

Vibrating horizontal. The vibrating horizontal screen is used extensively for suspended solids removal especially on hydraulic debarker effluents. The various makes operate basically similarly and differ mainly in mesh shape, screen surface size and shape, and vibratory action. The screen is usually set at a slight angle to the horizontal with the effluent entering at the high end. The effluent passes through the screen while the vibratory action moves the bark fines to the opposite end on a

rectangular screen and to the periphery on a circular screen where they are discharged. A schematic of the screen's operation and a photograph are shown in Figure 12. The efficiency of these screens in the reduction of suspended solids is variable depending on mesh size, influent suspended solids concentration, particle size distribution, and blinding tendency, but usually is in the range of 50 to 75%. The predominant complaint by mills using this type of screen is the high maintenance costs due to the vibration and because of mesh blinding; blinding can be the result of bark fines stapling or wedging, or the accumulation of pitch or slime. Some manufacturers claim they have overcome blinding by using automatic showers or wiper blades. Several years ago one manufacturer used plastic rings enclosed beneath the screen to provide continuous shear action for the removal of pitch, slime and bark fines from the screen. Several installations were made in the later 1960's but according to the manufacturer all have since been removed from service primarily due to pitch blinding of the rings, especially on softwood effluents. Also, the rings tended to wear their support screen, fall through, and end up plugging downstream equipment; in fact one mill complained of the rings finding their way to the clarifier and plugging the sludge pumps. This same supplier now provides a unit equipped with a continuous surface wiping device, but there are no known installations on debarker effluent. Most screen installations do not have any such accessories for continuous cleaning and rely on manual steaming and/or hosing for pitch, slime, or fines removal. Foaming on these screens has been reported at some installations and is probably due, at least in part, to high white water makeup rates and/or high flow rates across the screen. High influent solids content will tend to provide scouring action on the screen surface and aid in the removal of pitch and slime. The hydraulic capacity of these screens is highly variable depending on mesh size and influent characteristics but is usually in the range of 800 to 1600 l/min/m² (20 to 40 US gpm/ft²).

Cylindrical. Some mills use cylindrical screens for fine screening. This type of screen is a slightly inclined rotating drum similar in design and operation to rotary drainers. However, instead of a



(Photo courtesy of W.S. Tyler Co.)

FIGURE 12. VIBRATING HORIZONTAL SCREEN SCHEMATIC AND PHOTOGRAPH

perforated plate drum, a fine mesh screen is laid over a cylindrical frame. One west coast sawmill hydraulically debarking cedar built its own 12 mesh (woven stainless steel wire) cylindrical screen that has performed very well and has required little maintenance; showers above the screen continually backwash the mesh.

Inclined stationary. Inclined stationary screens are also frequently used for the removal of bark fines. The screen surface is nearly vertical at the top or feed end and becomes more horizontal at the bottom where the solids are discharged. The rejected solids are continuously washed down the surface by the influent and are discharged as they accumulate at the bottom. The operation of this type of screen is shown schematically in Figure 13 and a photograph is presented in Figure 14.

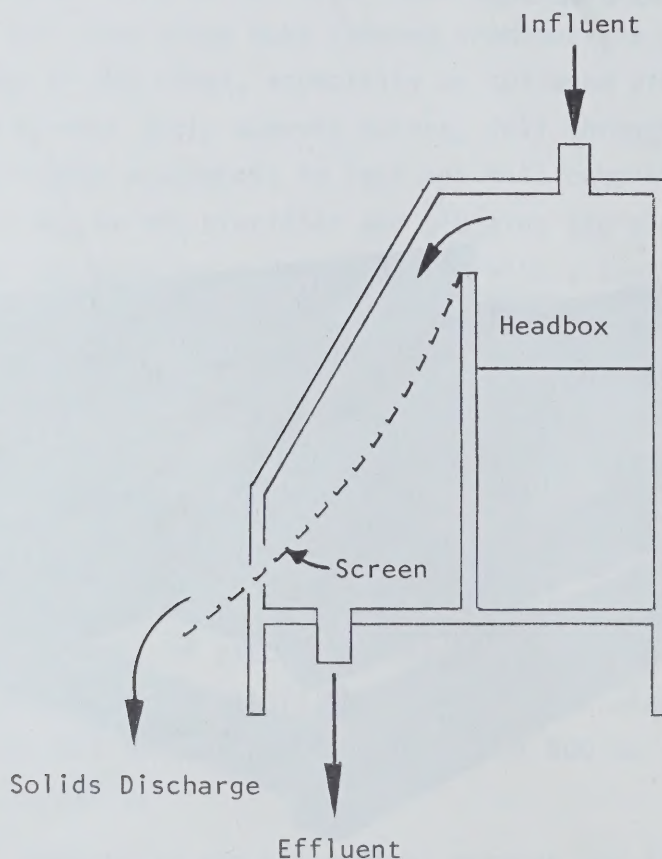
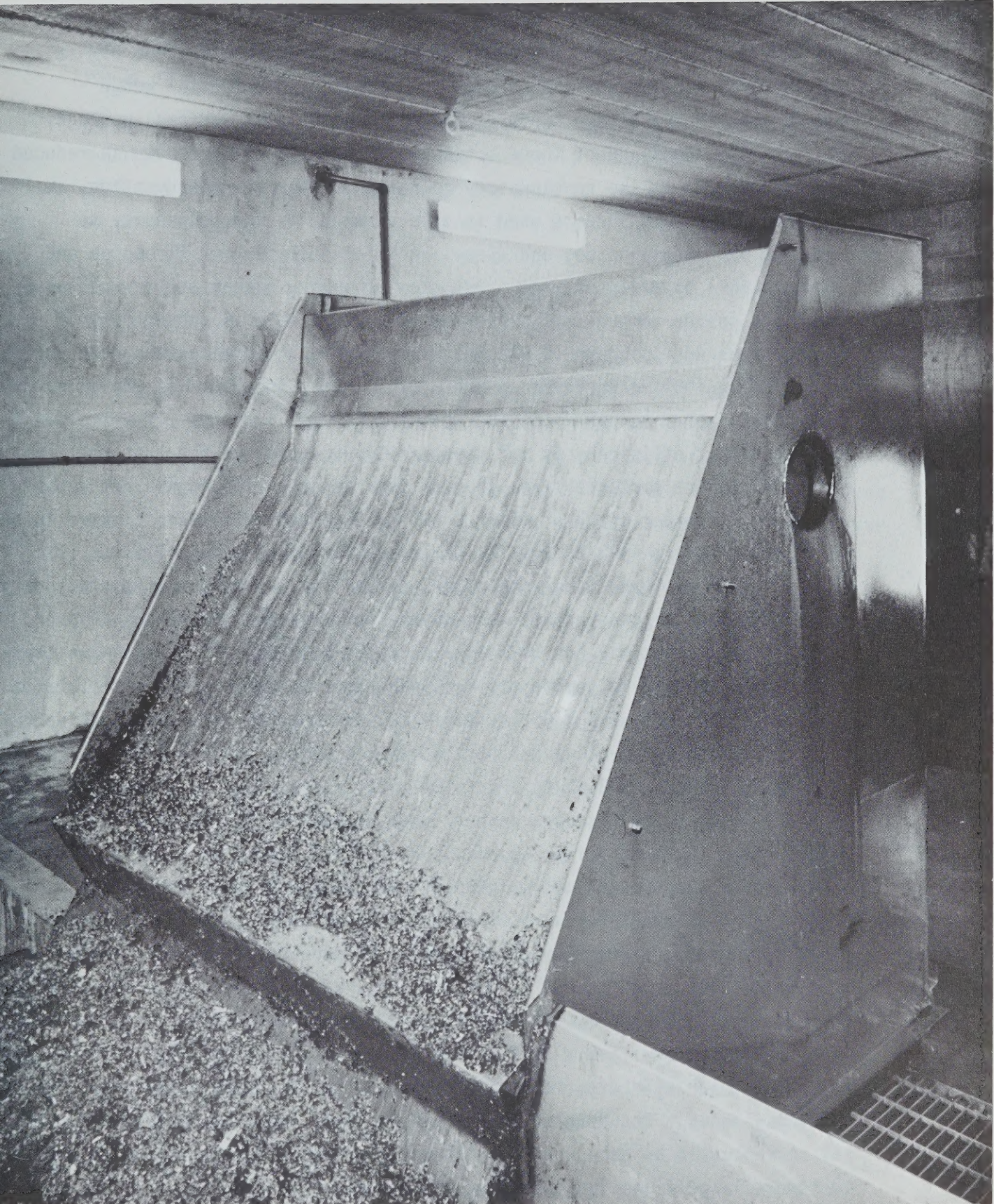


FIGURE 13. INCLINED STATIONARY SCREEN SCHEMATIC

The two predominant manufacturers of this screen for debarker effluent service are C-E Bauer (Hydrasieve) and Door-Oliver-Long (DSM). The Hydrasieve consists of three separate sloping sections angled from



(Photo courtesy of Bauer Bros. Co.)

FIGURE 14. TYPICAL INCLINED STATIONARY SCREEN

the verticle at 20° , 35° , and 45° from top to bottom, whereas the DSM is a continuously sloping surface through 45° . Both use horizontal wedge shaped wires for a screen surface which is available in various spacings.

The advantage of these screens over the vibrating screen is reduced maintenance due to the nonvibratory operation. The main disadvantage, as with other types of screens used in this service, is the propensity to plugging by fibres, pitch, and slime. A trial installation (Tremblay and Samson, 1969) on effluent from a wet drum debarking balsam and spruce had a suspended solids removal efficiency of 62% with a rejects consistency of about 11% using a 0.03 mm (0.012 in) wire spacing. Modifications made during the trial to improve performance included distribution vanes at the inlet and the addition of a screen vibration device to reduce foaming. It was also concluded that efficiency is not necessarily dependent on feed rate but on suspended solids particle size. During this trial, blinding was not experienced due to either pitch or fibre. Full scale feed rate was estimated to be about 1200 l/min/m (100 US gpm/ft) of screen width. One installation practicing summer wet drum debarking of 40% spruce and 60% balsam used stationary screens to dewater the rejects from several centrifugal separators (Rimmer, 1971). The screens did not blind due to pitch but had to be hosed down several times per shift to remove stapled and wedged bark fines. Test trials on a stationary screen with 0.35 mm (0.014 in) spacings on a wet drum effluent after treatment in a rotary drainer had an efficiency of 45%, reducing the suspended solids from 2000 mg/l to 1100 mg/l; the rejects consistency was 12 to 15%. Tests using a screen with a large opening of 0.7 mm (0.028 in) plugged quickly from fibre stapling, whereas the smaller opening screen did not. One manufacturer reported trials on hydraulic debarker effluent from cedar processing which were mostly unsuccessful due to blinding and stapling by the bark fines; mesh size, flow rate and other details were not mentioned. More success has been experienced on wet drum debarkers, where one manufacture has recommended 0.5 mm (0.020 in) spacing on coarse screened effluent. One such installation using a 1.8 m (6 ft) wide screen handles 1500 l/min (400 US gpm) of effluent for a loading rate of 830 l/min/m and produces rejects of 8 to 10% consistency. It has also been suggested that the coarser 1.5 mm (0.06 in) screen could be used when centrifugal separators are to follow in order to remove large fines that may plug the separators.

As with other treatment equipment used on debarker effluents, performance is very site specific, but loadings are generally in the range of 600 to 1200 l/min/m (50 to 100 US gpm/ft) of screen width.

Rotary microstrainer. The rotary microstrainer is a horizontally mounted rotating cylindrical screen partially submerged where the effluent passes from the inside of the drum to the outside. A photograph of this equipment is shown in Figure 15. The suspended solids that accumulate on the interior of the screen are washed or blown into a centrally located trough for removal. (Wash water requirements are in the range of 1 to 3% of total flow.) Microstrainers have been used widely for many years in water treatment and more recently for the removal of suspended solids in wastewaters. The use of the rotary microstrainer for the removal of bark fines from wet debarker effluents has been studied on both a laboratory and pilot scale level (Envirocon, 1976); there are no known full scale units on debarker effluents. It was concluded that the microstrainer is a viable alternative to the clarifier for the removal of bark fines that can consistently yield effluent suspended solids levels of less than 100 mg/l. A modification of the standard screen that improved screen performance was blanking off a portion of the screen adjacent to the feed inlet to prevent mat destruction by the influent velocity. Although a bark fines particle size distribution indicated that the efficiency may be low (as much as 40% of the fines passed through a 400 mesh screen), it was found that the removal efficiency was a function of the fibre mat build-up on the polyester screen and not so much the mesh size (mesh sizes of 190, 229 and 305 were tested). Efficiencies consistently over 90% were achieved when a mat of 0.20 kg/m^2 (0.04 lb/ft^2) was maintained; hydraulic loadings were in the range of 200 - 400 l/min/m² (5 to 10 US gpm/ft²). Stapling was also prevented at the higher mat weight. It was also found that the efficiency was not a function of the wood species debarked, at least for cedar, spruce and hemlock (hemlock and balsam).

Concluded advantages of the rotary microstrainer over sedimentation techniques include up to one-tenth the space requirements because of the higher hydraulic loadings, higher efficiency and a lower suspended

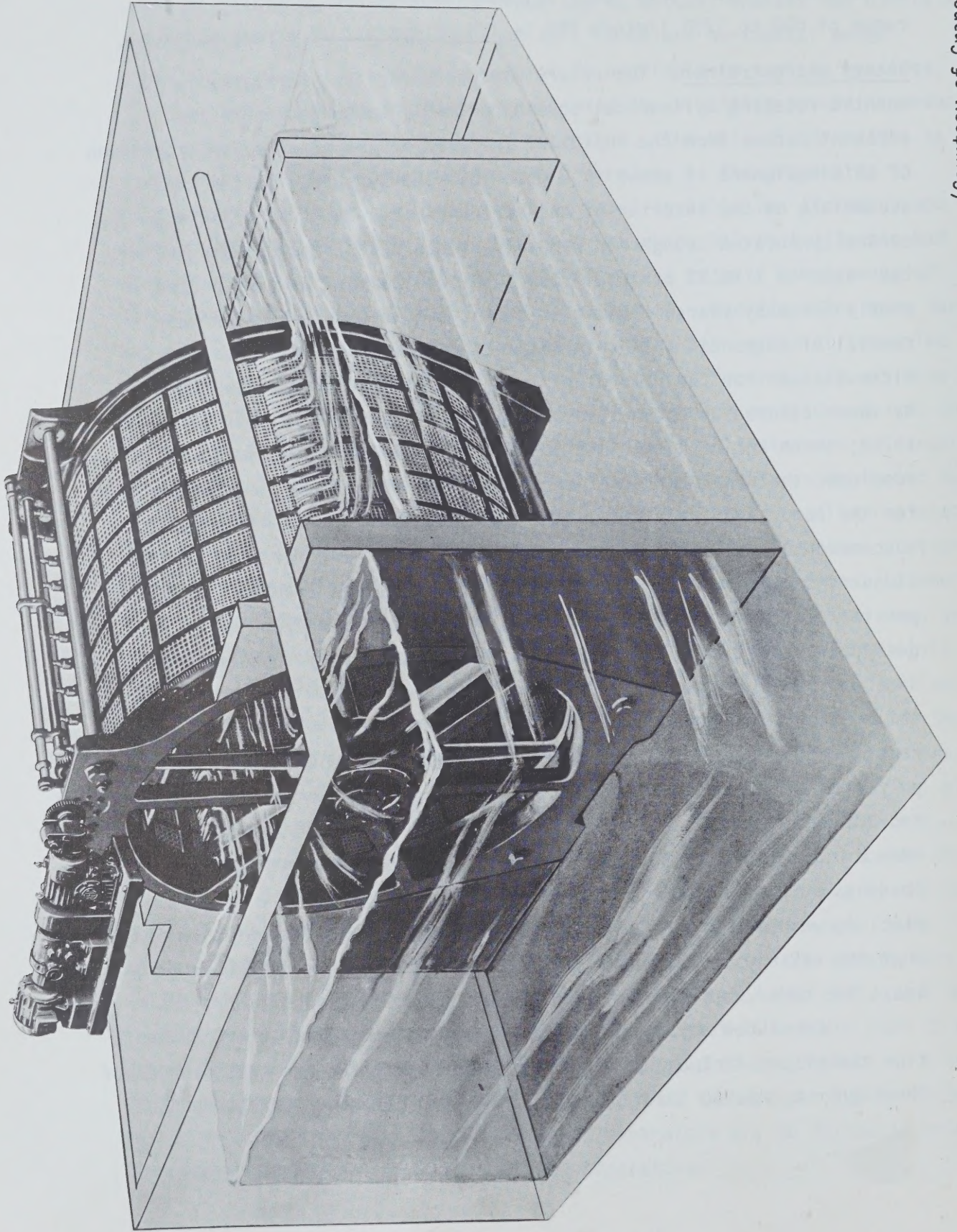


FIGURE 15. TYPICAL MICROSTRAINER

(Courtesy of Crane Co.)

solids concentration in the effluent, less installed cost, and potentially less BOD_5 and toxicity in the effluent due to substantially less contact time between the bark fines and the water. Potential pitch build-up on the screen was not discussed; however, because of the constant back-flush to remove the fibre mat, pitch build-up should be minimal. Sludge consistency also was not mentioned but will be a function of the amount of back-flush water employed and municipal applications data indicated it should be similar to that of a clarifier, in the range of 2 to 5%. Slime build-up may be a problem but also should be minimized by the constant back-flush; if necessary, ultraviolet lights can be installed over the screen or the unit can be periodically taken out of service and cleaned. One disadvantage of the microstrainer relative to the clarifier is its inability to handle surges, and for optimum performance upstream surge capacity should be provided. Furthermore, if the feed suspended solids concentration is low (less than 1000 mg/l) then it may be difficult to establish the required mat density on the screen. This problem may be overcome by recycling a portion of the rejects in order to increase the solids loading. Like a clarifier, sludge dewatering equipment is required.

Rotostrainer. Another type of screen that shows promise for the removal of bark fines is the Rotostrainer manufactured by Hydrocyclonics. This cylindrically shaped screen is not a mesh but a continuous helical band of 304 stainless steel wire. It is exterior fed, unlike the interior feed of the microstrainer, and the screen mat is removed with a doctor blade. The operation of this screen is shown schematically in Figure 16 and a photograph is presented in Figure 17. One advantage of this screen is that it is self-cleaning; the effluent falls through the interior of the screen and continuously purges the bottom of the screen, therefore eliminating the need for an external wash. As with the microstrainer the fibre mat does most of the screening and so some operating attention is required to ensure that the rotational speed permits the formation of a mat. Apart from this the only apparent disadvantage is that, unlike the horizontal vibratory or stationary screen, it cannot tolerate flow surges, and therefore a surge tank or headbox with recycled overflow should be provided.

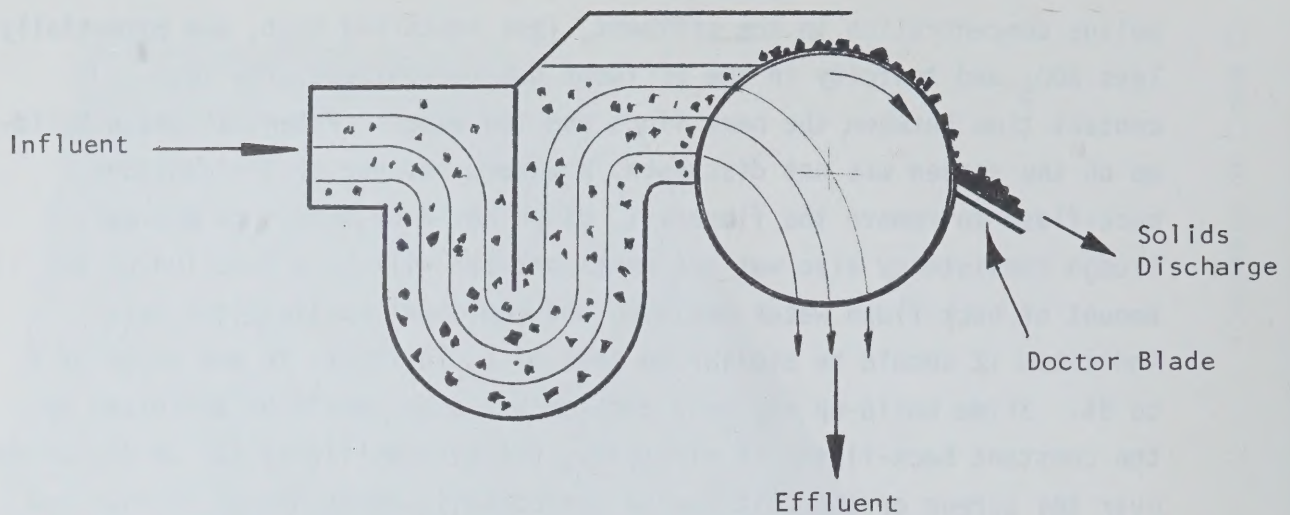
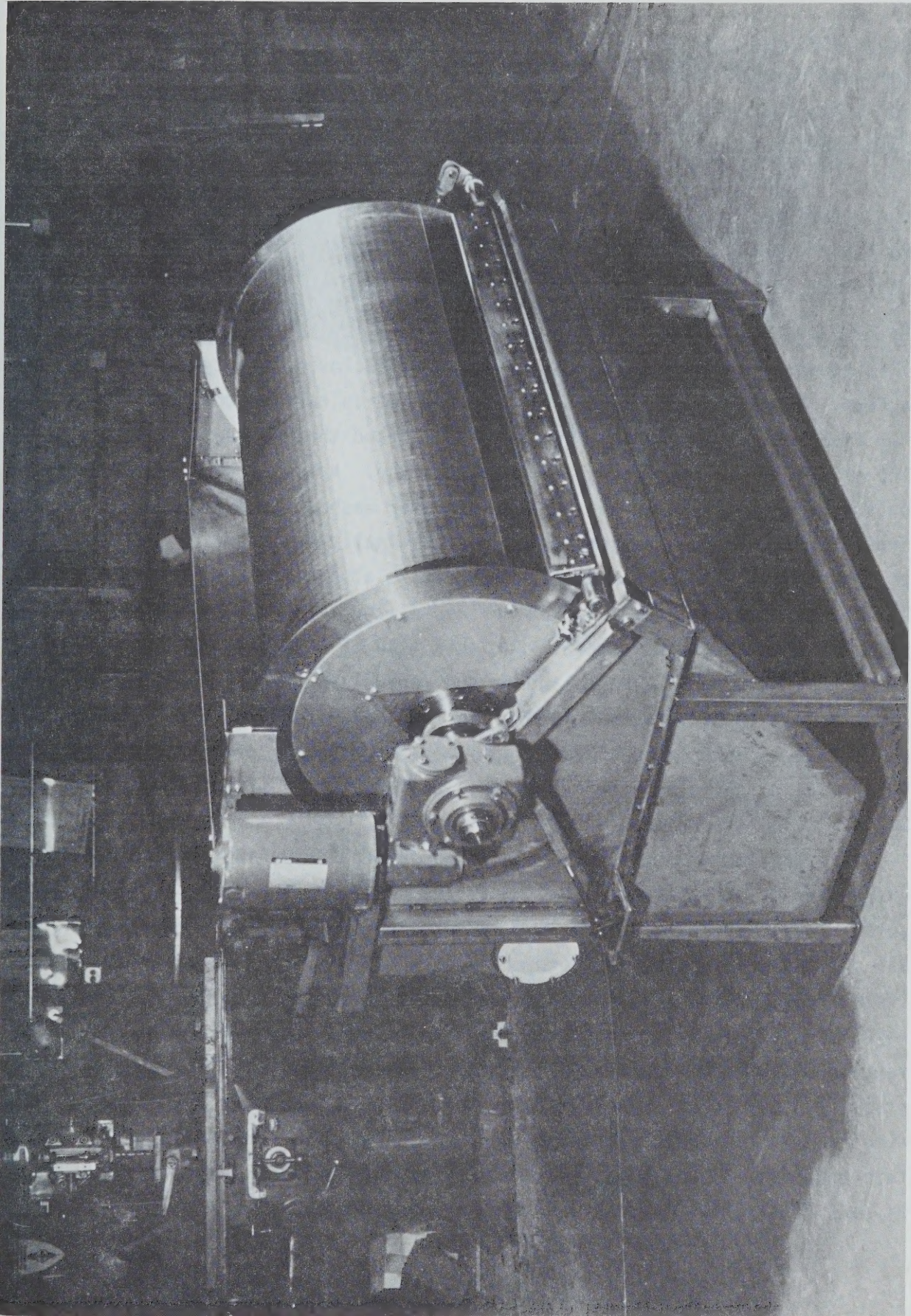


FIGURE 16. ROTOSTRAINER SCHEMATIC

At one hydraulic debarker effluent installation where a 0.50 mm (0.02 in) screen opening was used in parallel with a 0.84 mm (0.03 in) vibrating horizontal screen the average efficiency was 85% compared to 59% for the vibrating screen. Generally it was found that the suspended solids removal efficiency was proportional to the inlet consistency and that maximum efficiency (90%) was achieved at 1500 mg/l or higher inlet suspended solids concentration (at a feed concentration of 500 mg/l the efficiency was 40%). The screen performed better at hydraulic loadings of 800 l/min/m² (20 US gpm/ft²) of screen area and up to 1300 l/min/m² (30 US gpm/ft²); the 1.2 m x 3.0 m (4 ft x 10 ft) vibrating screen had a clean capacity of 4160 l/min but only averaged about 3030 l/min or 815 l/min/m² (20 US gpm/ft²) due to partial plugging. The accepts from the Rotostrainer averaged 310 mg/l versus 450 mg/l for the vibrating screen. It was concluded that the maintenance requirements for the Rotostrainer would be less than those for the vibrating screen because of the absence of vibration and reduced propensity for plugging (the Rotostrainer had to be hosed down once per week and the vibrating screen twice per shift).

Contrary to this experience was a pilot Rotostrainer installation (Lemay et al., 1976) on a drum debarker effluent using papermill white water for makeup that had a suspended solids removal efficiency of only 18% with 0.80 mm (0.03 in) spacings. (A 0.25 mm screen was initially tried but plugged quickly.) The feed suspended solids concentration was



(Photo courtesy of Hydrocyclonics Corp.)

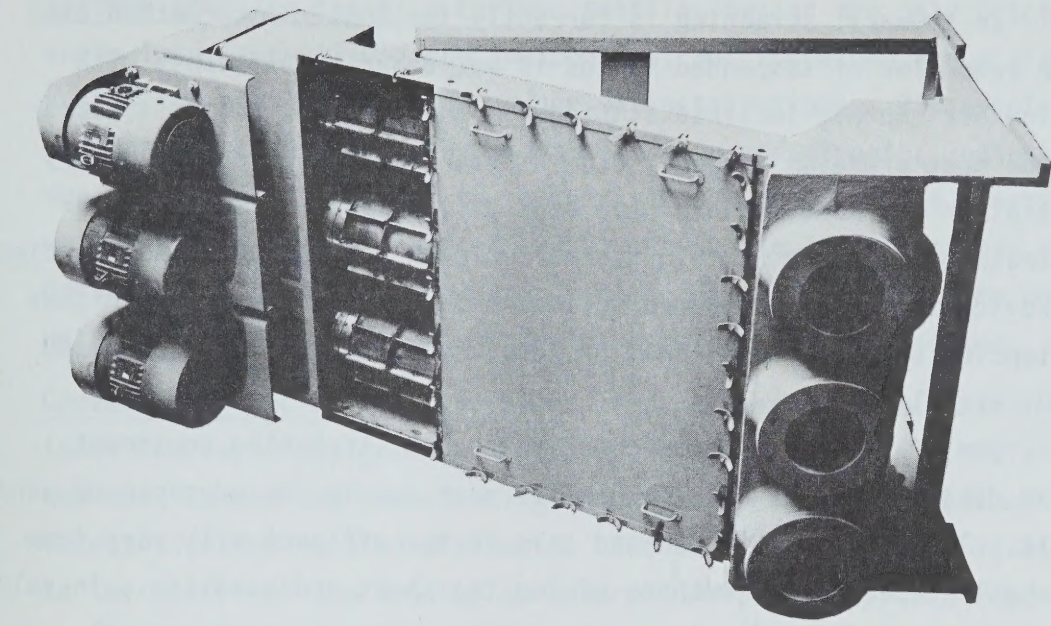
FIGURE 17. ROTOSTRAINER

about 4000 mg/l and the rejects consistency 10%. It was concluded that the poor results were due to the high percentage of fines. Whether a mat for filtering was permitted to develop was not discussed, and it may have been that the screen rotational speed was too high to permit this.

Although it has been demonstrated that the Rotostrainer, like the rotary microstrainer, may provide increased solids removal compared to other types of fine screens currently in use, this would have to be confirmed by pilot testing on a site specific basis.

Water extractor. Another type of screening device is the water extractor. This equipment consists of an inclined screw enclosed in a cylindrical screen. The effluent enters at the bottom and is carried upwards through the cylinder by the screw. The water is forced through the screen by the screw and the solids discharged at the top. Nylon or stainless steel brushes are usually used for continuous water wash. The extractor is shown in Figure 18. This equipment was originally designed for thickening pulp stock but with a few modifications it is also being used to remove bark fines from wet drum debarker effluents, and there are several in this service in eastern Canada. For this type of installation the triple screw unit is common. The cylinders and screws are usually 304 stainless steel with 1.59 mm (0.0625 in) holes in the cylinders. The flow rate can be as high as 3800 l/min (1000 US gpm) per screw but is often lower due to partial plugging by fines or pitch. Similarly, the efficiency can be 50% but is quite variable.

One wet drum debarking operation (Boegh, 1969) installed water extractors on the effluent from the rotary drainer. The effluent suspended solids level was reduced from 3900 mg/l to 2600 mg/l for an efficiency of 33% and the consistency of the discharged fines was 10%. At a similar installation (Rimmer, 1971) the extractors produced 10 to 15% consistency rejects. At this location 60% of the accepts were recycled and the remainder pumped to centrifugal separators; with this level of recycle, stapling occurred in the extractors, thereby reducing their capacity and requiring the installation of another unit. The main complaint about this equipment is the high maintenance costs due to brush wear, plugging by bark fines or pitch, and wear due to sand abrasion.



(Photo Courtesy of Voith-Morden Ltd.)

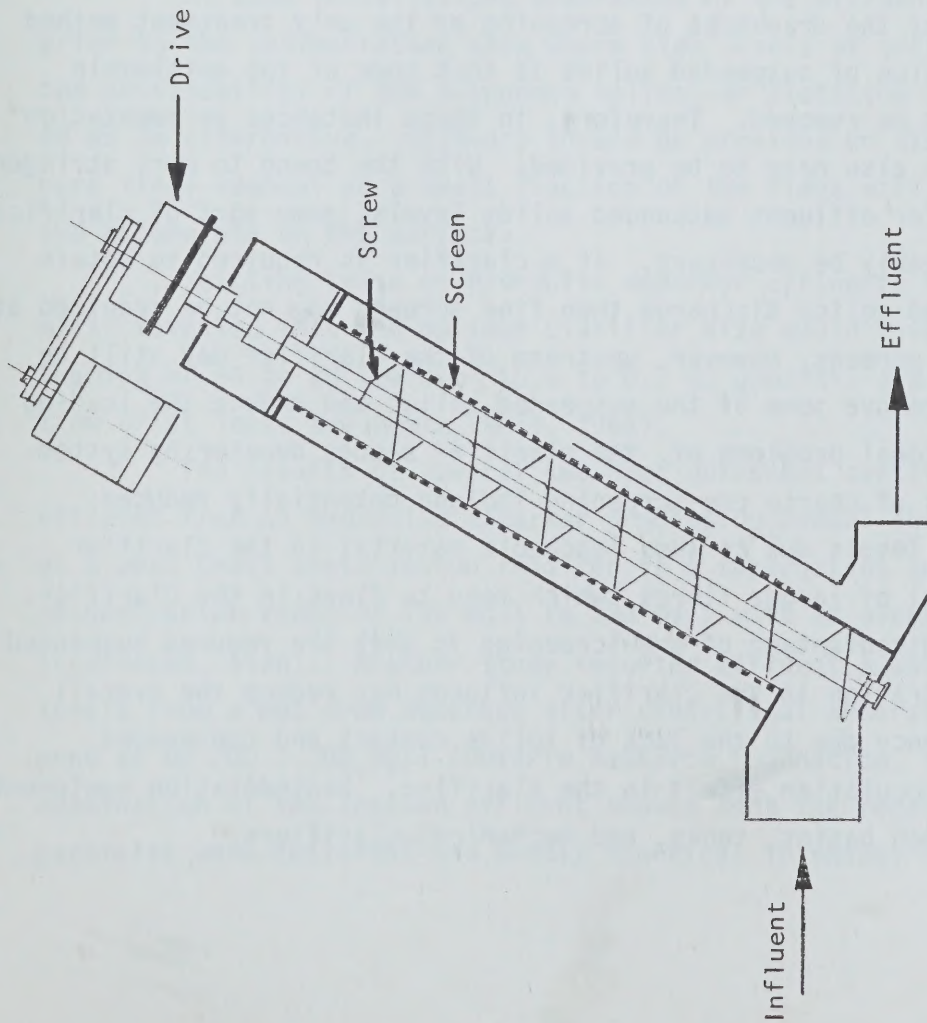


FIGURE 18. WATER EXTRACTOR SCHEMATIC AND PHOTOGRAPH

In summary, screening is currently the most common method used for the reduction of suspended solids in wet debarker effluents with vibrating horizontal, inclined stationary, and water extractor screens being the most prevalent types. Other screen types such as the rotary microstrainer and Rotostrainer have been piloted in this service and demonstrate good potential. In general, higher screen feed consistencies will provide increased suspended solids removal efficiencies and higher consistencies can be accomplished by less water usage and/or increased effluent recycling.

One of the most common complaints about screening equipment treating debarker effluents is excessive wear due to the presence of sand and silt. The quantity of sand and silt in the effluent will vary from mill to mill depending on methods of log transport and handling. Installations with high levels of grit should provide adequate grit removal facilities to minimize wear on screens and other equipment.

6.2.2 Sedimentation

One of the drawbacks of screening as the only treatment method for the reduction of suspended solids is that some of the settleable solids may not be removed. Therefore, in these instances sedimentation facilities may also have to be provided. With the trend to more stringent requirements for effluent suspended solids levels, some sort of clarification will probably be necessary. If a clarifier is required to obtain lower suspended solids discharge then fine screens may not be required at all. Coarser screens, however, upstream of the clarifier may still be desirable to remove some of the suspended solids and reduce the loading on and operational problems of, the clarifier sludge dewatering system. Other benefits of coarse pre-screening include potentially reduced effluent BOD_5 levels due to less leachable material in the clarifier and the removal of larger fibres, which tend to float in the clarifier. One possible disadvantage of pre-screening is that the reduced suspended solids concentration in the clarifier influent may reduce the overall system efficiency due to the lack of solids contact and consequent mechanical flocculation effect in the clarifier. Sedimentation equipment includes earthen basins, tanks, and mechanical clarifiers.

Earthen settling basins. Earthen settling basins are only practical where land is available and inexpensive, and therefore are a viable option for a relatively few number of installations. Disadvantages include operating costs for sludge dredging and disposal, potential odour due to anaerobic decay of the accumulated sludge, and the leaching of water soluble organics into the effluent due to the relatively long contact time of sludge and water. Also, performance tends to continually deteriorate between dredgings as the usable volume is reduced.

Conventional mechanical clarifier. The conventional mechanical clarifier is of two basic designs, rectangular and circular, with circular being the most common and experiencing widespread use in the treatment of forest industry related effluents. The clarifier influent is usually fed to the center of the unit by an underground pipe (overhead feed and peripheral feed are also used) and discharged to the feedwell that distributes this flow radially. The clarifier operation is shown schematically in Figure 19.

At some installations deaeration of the effluent may be required prior to the sedimentation step where high levels of entrained air reduce the settleability of the suspended solids; or flotation should be considered as an alternative. Skimmers should be provided on clarifiers used for bark fines removal as a small fraction of the fines will tend to float and accumulate on the surface.

Settling tests on hydraulic debarker effluents from several mills revealed that the optimum clarifier size would have a hydraulic loading of 24 to 28 l/min/m² (0.6 to 0.7 US gpm/ft²) and a retention time of at least two hours (NCSI, 1966).

The results of several two-hour quiescent settling tests on the effluent from an hydraulic debarker processing hembal (hemlock and balsam) at a west coast installation resulted in a supernatant suspended solids concentration range of 136 mg/l to 283 mg/l with an average of 205 mg/l (Envirocon, 1976). Another study reported effluent suspended solids levels from a wet drum debarker after centrifugal separation and settling pond to be 200 - 300 mg/l (Ontario Research Foundation, 1972). Microscopic examination of the settled effluent showed that the remaining suspended particles were colloidal and mostly spherical in shape; the bark fines

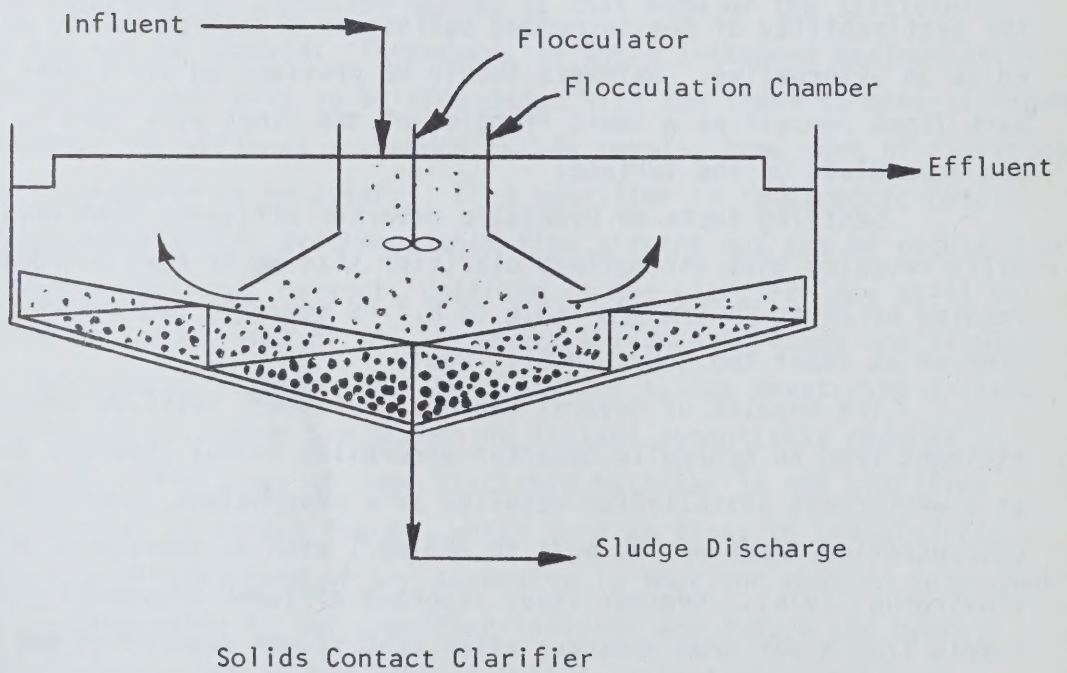
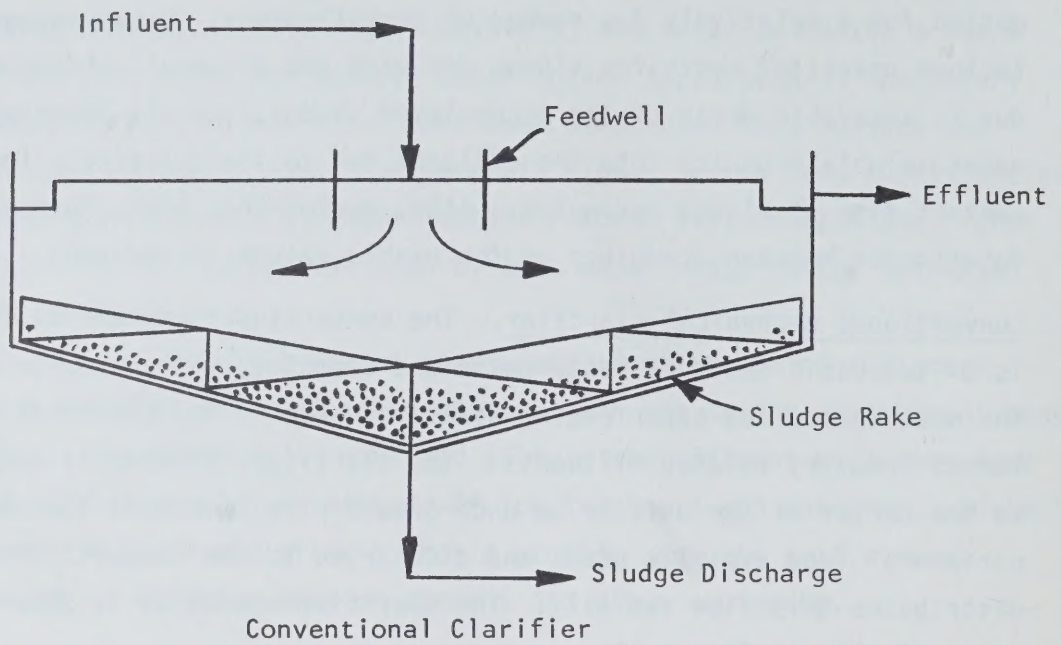


FIGURE 19. CONVENTIONAL CLARIFIER AND SOLIDS CONTACT CLARIFIER SCHEMATIC

content was very low. It was concluded that the measured suspended solids in settled debarker effluents are non-cellulosic in nature and that the character is comparable to a stable emulsion. This was confirmed by the failure of several different coagulants and flocculants to appreciably reduce the suspended solids level further. However, experience at some northwest U.S. mills with hydraulic debarkers is that coagulants are successful in improving the reduction of suspended solids in clarifiers.

Laboratory settling tests (Kronis and Holder, 1968) on wet debarker effluents after prescreening with a 28 mesh screen found that 40 to 70% of the suspended solids were removed regardless of the initial concentration; almost all the settling took place in the first 15 minutes. It was concluded that simple clarification would not be adequate to consistently reduce the suspended solids to a low level (i.e. 50 mg/l).

With the advent of more restrictive effluent standards, increased reduction of suspended solids in final effluents will be required. This means improved methods of sedimentation or wider use of other suspended solids removal equipment such as filtration. A potential method for improved sedimentation is the use of the solids contact clarifier, with or without the use of chemicals to promote coagulation and flocculation.

Solids contact clarifier. The solids contact clarifier (SCC), which has been used extensively in water treatment, is basically a conventional clarifier with a flocculation chamber and the capability to retain more sludge. A schematic of this type of clarifier is shown in Figure 19. The feed enters the flocculation chamber and then flows down and exits at the bottom, passing through the previously settled sludge. Slow stirrers in the flocculation chamber provide gentle mixing of the influent, promoting mechanical flocculation (chemical coagulants and/or flocculants may be added to improve performance). Further flocculation and solids filtering occurs as the influent passes through the sludge blanket. The overall effect is improved removal of settleable solids and the removal of some of the non-settleable solids. A recent study (IEC, 1975) of the SCC on pulp and paper effluents (although not including debarker effluents specifically) found that the SCC was more effective than the conventional

clarifier in the removal of suspended solids. It was concluded that because of its higher cost the SCC would probably not be universally accepted for this service but would have to be justified on a per site basis depending on effluent requirements, alternative methods available, etc. A conventional clarifier that has some excess capacity can be retrofitted to some extent to operate like a SCC by replacing the feedwell with a flocculation chamber and flocculators, and recirculating some of the clarifier sludge to the clarifier feed. Because of the larger retained sludge volume of the SCC compared to the conventional clarifier, it is more susceptible to upset and upstream surge capacity may be required where such surges are prevalent.

Further solids removal can usually be achieved by the addition of appropriate coagulating and flocculating chemicals. The terms coagulation and flocculation are often used interchangeably but strictly speaking coagulation is the reduction of particle surface charges and flocculation involves the bridging of particles by the flocculant as well as particle charge neutralization. Typical coagulants are alum, lime, and ferric chloride; flocculants are high molecular weight organic polyelectrolytes. Chemical coagulation of log pond water, which is similar to debarker effluent, using alum at an optimum pH of 5.5 and a dosage of 125 mg/l reduced the BOD_5 , COD and TSS by as much as 49, 67 and 96%, respectively (Hoffbuhr et al., 1971). Kronis and Holder (1968) compared several methods including screening, filtration, centrifuging, air flotation, and sedimentation on a laboratory scale for suspended solids reduction from a wet drum debarker effluent and concluded that chemically assisted sedimentation was the most successful. However, the polymer dosage levels required to achieve 50 mg/l of suspended solids were high (up to 30 mg/l) and, therefore, prohibitively expensive. The tests were run on effluent after passing through a rotary drainer and a 28 mesh vibrating screen. Suspended solids levels after this preliminary treatment were in the 200 to 800 mg/l range. It was found that different coagulants were successful on different effluents. It was also found that the older the effluent the less coagulant that was required to achieve the same level of removal (and if aged long enough would self coagulate and settle). Also, it was speculated that the required dosage

was proportional to the concentration of water soluble extractives (this implies that effluent from water driven logs that have had some organics extracted should be easier to coagulate). In general it was found that if fresh effluent was coagulated the floc would tend to float whereas for aged effluent it settled. This behaviour was attributed to the presence of dissolved air in the fresh effluent that gradually dissipated over time. Tests on deaerated effluent provided much better settling and a firmer, more stable sludge. The aging time required for flotation to change to sedimentation was three to four hours. Kronis reported later after further testing (CPPA, 1968) that mechanical clarification of wet drum debarker effluents after coarse screening with a suspended solids concentration of 2000 mg/l yielded effluents with about 250 mg/l. Chemical flocculation with various polymers at dosages of about 0.5 mg/l was very successful in reducing this further provided that alum or lime was used as a primary coagulant.

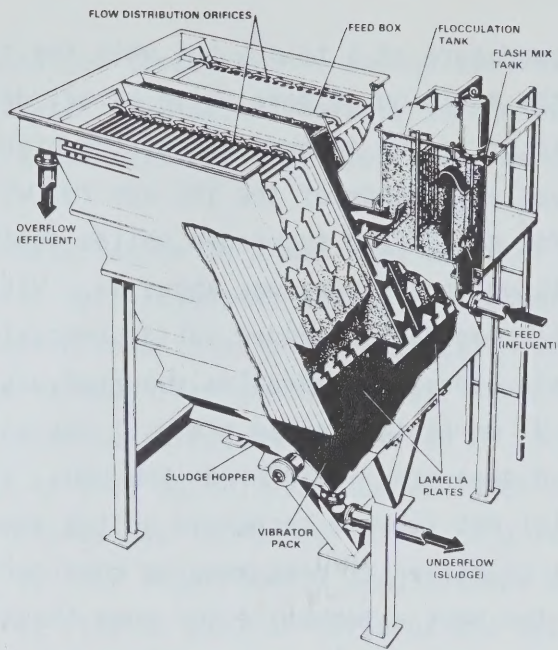
A full scale chemically coagulated sedimentation installation reported (Roden and De Hass, 1971) using about 60 mg/l of alum and 1 mg/l of polyelectrolyte on an hydraulic debarker effluent yielding an effluent suspended solids concentration of about 50 mg/l. It was found that at alum dosages up to 20 mg/l no improvement in suspended solids removal occurred, but that improvement was constant from 20 to 60 mg/l after which increased dosage had negligible effect. Removal efficiency was 97% at a clarifier hydraulic loading rate of 30 l/min/m^2 (0.75 US gpm/ft^2) and a retention time of 2.25 hours. It was concluded after running for some time that the effluent suspended solids concentration was more dependent on influent solids composition than concentration.

A Finnish study (Jensen and Meloni, 1974) using alum, ferrous sulphate and fly ash for the chemical treatment of wet debarker effluent from the debarking of pine found that the BOD_7 , suspended solids, and colour were substantially reduced. Alum at dosages of 200 to 400 mg/l and fly ash at dosages of 1 g/l gave the best results, reducing the BOD_7 but about 60%, the TSS by over 95% and colour by more than 90%. Both chemicals increased the sludge volume over that of mechanical sludge but for both chemicals the sludge filterability was improved, especially the fly ash sludge.

Disadvantages of the SCC compared to the conventional clarifier include higher capital cost and greater susceptibility to upset. Also, if chemicals are used the resultant sludges are often more difficult to dewater (Jensen and Meloni's findings tend to dispute this, and although it is not surprising that the fly ash sludge was easier to dewater, it would be expected that the alum sludge would be more difficult). The high capital costs can be minimized by recycling screened effluent prior to sedimentation so that only the discharge effluent is so treated; this is possible for wet drum debarkers where very low levels of suspended solids in the recycled water is not required but may not be for hydraulic debarkers.

Inclined plate clarifier. The inclined plate clarifier (IPC) is gaining popularity as an alternative to the conventional circular clarifier for the removal of suspended solids. The inclined plate clarifier consists of a series of parallel plates angled 45° or 55° to the horizontal (55° is recommended for this type of service because of the relatively low specific gravity of barkfines) providing a considerably larger effective settling area in a smaller total area. An inclined plate clarifier is shown in Figure 20. The operating principle is based on the fact that the capacity of a gravity settler is dependent on the settling area and not the settling depth. The main advantage over the conventional clarifier is that it requires as little as one-tenth the area, and there are no moving parts, resulting in lower power costs and potentially less maintenance costs. This permits its use at more sites than the conventional clarifier and also allows closer proximity to associated equipment thereby reducing piping and pumping costs. Potential disadvantages include less sludge storage capacity and plant fouling due to clinging sludges or slime growth. Tube settlers are based on the same principle and design but use tubes rather than plates. A conventional clarifier can be retrofitted with one or more modules of these tubes or plates to increase its capacity.

An inclined plate clarifier was installed to treat the screened effluent from a wet drum debarker using white water as makeup as reported by Lemay et al. (1976). It was found that the solids did not settle, due to the presence of air. The effluent did not readily deaerate at the



(Courtesy of Axel Johnson Industries Ltd.)

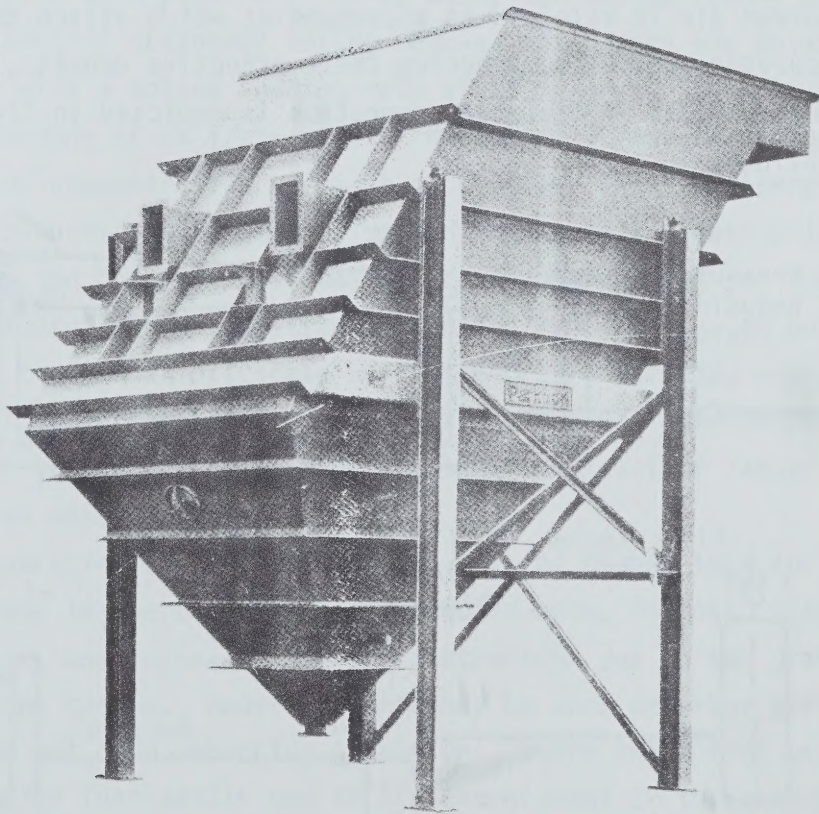


FIGURE 20. INCLINED PLATE CLARIFIER SCHEMATIC AND PHOTOGRAPH

existing temperature of 4 to 8°C but when the temperature was increased to 20°C by the addition of more white water, deaeration was successful. With the help of vacuum deaeration and the higher temperature, the suspended solids removal efficiency of the IPC was 70% with a hydraulic loading rate of 10 l/min/m² and a feed suspended solids concentration of about 4500 mg/l; the sludge consistency was about 5%. With the addition of 2 mg/l of an anionic polymer the suspended solids removal efficiency was increased to 86%. The main operational problem reported was the daily cleaning required between the 51 mm (2 in) spaced plates. The total installed cost of the clarifier and deaerator in 1975 was \$80,000. Although the inclined plate separator will not improve suspended solids removal relative to the conventional clarifier it does require considerably less space and therefore may be the best alternative for some installations.

6.2.3 Flotation

In this process a flocculated suspension is pressurized with air and discharged at atmospheric pressure to a flotation tank where the dissolved air is released as microbubbles which attach themselves to the flocculated particles, reducing their effective density, and floating them to the surface. A flotation operation is depicted in Figure 21.

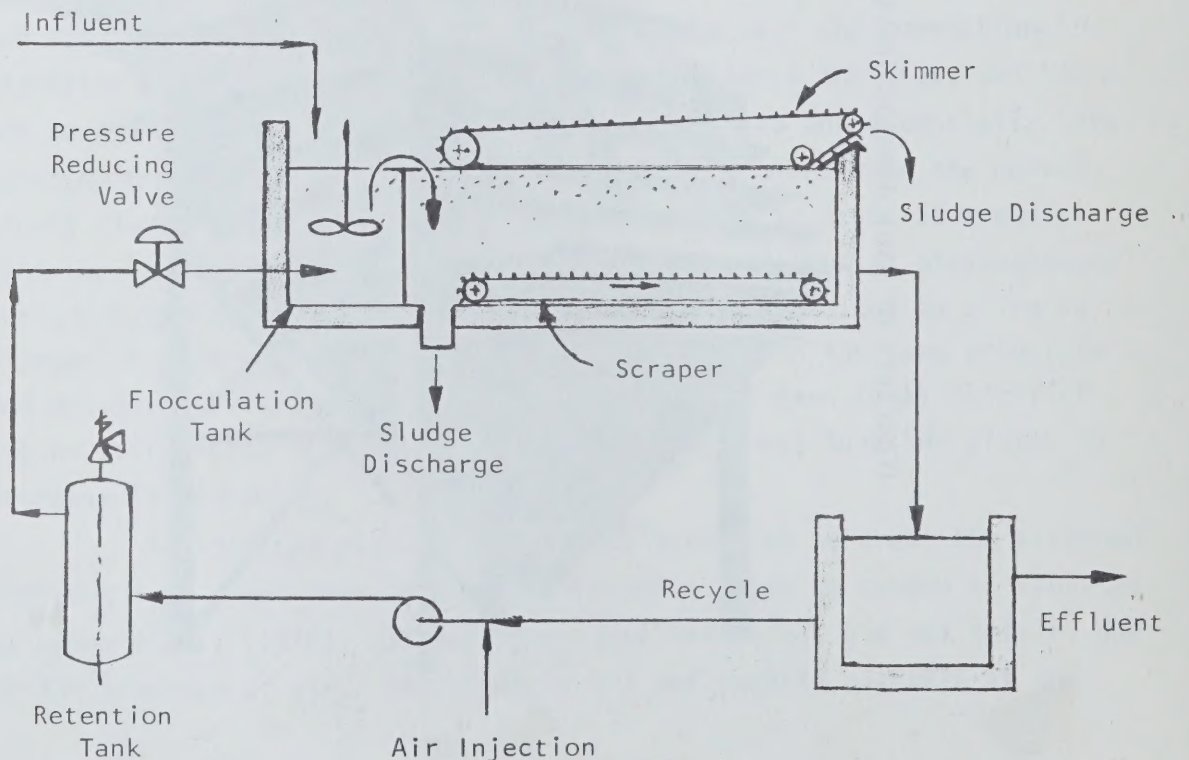


FIGURE 21. TYPICAL FLOTATION OPERATION

Preliminary flotation tests (Kronis and Holder, 1968) on a wet drum effluent found that with chemical coagulants the suspended solids levels could be reduced to 50 mg/l but that flotation was unsatisfactory without chemicals.

A pilot plant installation on a wet drum debarker using paper mill white water with a 50 mg/l suspended solids concentration for makeup, reported optimal performance results of an 86% reduction in suspended solids and 45% reduction in BOD_5 (Valiquette, 1976). This was achieved with an average inlet suspended solids concentration of 2500 - 3000 mg/l and a BOD_5 concentration of 2500 mg/l. With the addition of 1 mg/l of anionic polymer the efficiency was increased to 93% at a feed rate of 94 l/min/m² (2.3 US gpm/ft²). Air requirements were between 0.07 and 0.21 m³/1000 l (1 and 3 ft³/100 US gal) of influent and solids loading rate was 20 kg/hr/m² (4 lb/hr/ft²). The float sludge consistency was 5.0%.

Another pilot plant operation was performed on screened debarker effluent that also used paper mill white water for makeup (Lemay et al., 1976). Fifty percent suspended solids removal efficiency was obtained using only air with a solids loading rate of 15 kg/hr/m² (3 lb/hr/ft²), an hydraulic loading of 69 l/min/m² (1.7 US gpm/ft²), and an influent suspended solids concentration of about 3500 mg/l. The efficiency was increased to 75% using 100 mg/l of alum and 1 mg/l of cationic polymer. In 1973 dollars the chemical cost was about \$10/day or 0.8¢ per 1000 litres. The floated sludge consistency varied from 1.3 to 3.4% but it was postulated that in a full scale unit with proper skimming equipment it would be 4 to 5%. The relatively low efficiency was attributed to the screening prior to flotation and the resultant low level of larger particles in the flotation unit feed.

The operating costs for flotation will be higher than for sedimentation due to the compressed air requirements, in most cases the use of chemicals, and increased operating attention due to the greater complexity of the system. However, there may be some debarker effluents, especially from wet drum debarking operations, where the solids will float more readily than settle due to air entrainment or the nature of the solids (the makeup water may contain a high level of floatable fibre)

and, therefore, flotation will be the best option. In any case there are no known full scale flotation equipment installations for the removal of bark fines from wet debarker effluents in North America. There are, however, some in Europe and one supplier reports results from a Finnish installation that uses no chemicals and produces an effluent with a suspended solids concentration of 190 mg/l with a removal efficiency of 92%.

6.2.4 Centrifugal separators

Centrifugal separators are widely used in the pulp and paper industry for removing grit and heavy solids from fibrous streams. In the last few years they have also been employed for the removal of suspended solids from wet debarker effluents, especially at wet drum debarker installations in eastern Canada.

As the name suggests the centrifugal separator removes solids from the liquid by centrifugal action. The effluent must be pumped to this equipment in order to develop the pressure required for proper operation. A schematic showing the operation of a centrifugal separator is shown in Figure 22; a photograph is presented in Figure 23. Selection of the correct reject nozzle size is important; if it is too small it may plug and if too large, although it may be more efficient in suspended solids removal, the rejects stream flow rate will be larger with a lower consistency that then must be dewatered.

One of the first installations, reported by Wetmore (1968), of a centrifugal separator on debarker effluent was intended to concentrate the effluent prior to fine screening. The mill employed wet drum debarking and processed hardwoods. This approach greatly reduced the screen size requirement and at the same time improved the screen efficiency as the fine particles were removed by the larger particles that formed a mat on the screen. Four separators, in parallel, with 38 mm (1.5 in) reject nozzles and each handling 1700 l/min at a 345 kPa (50 psi) pressure drop were used. They each produced rejects at about 75 l/min having a consistency of about 2% which were fed to the vibrating screen. The feed suspended solids concentration averaged 2000 mg/l and the accepts 1200 mg/l, for an efficiency of 40%. Earlier trials indicated that this efficiency could be increased by increasing the pressure drop across the separator.

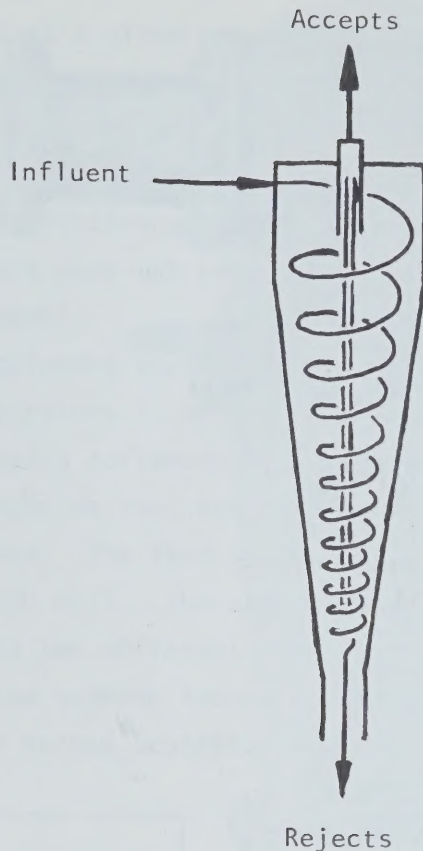
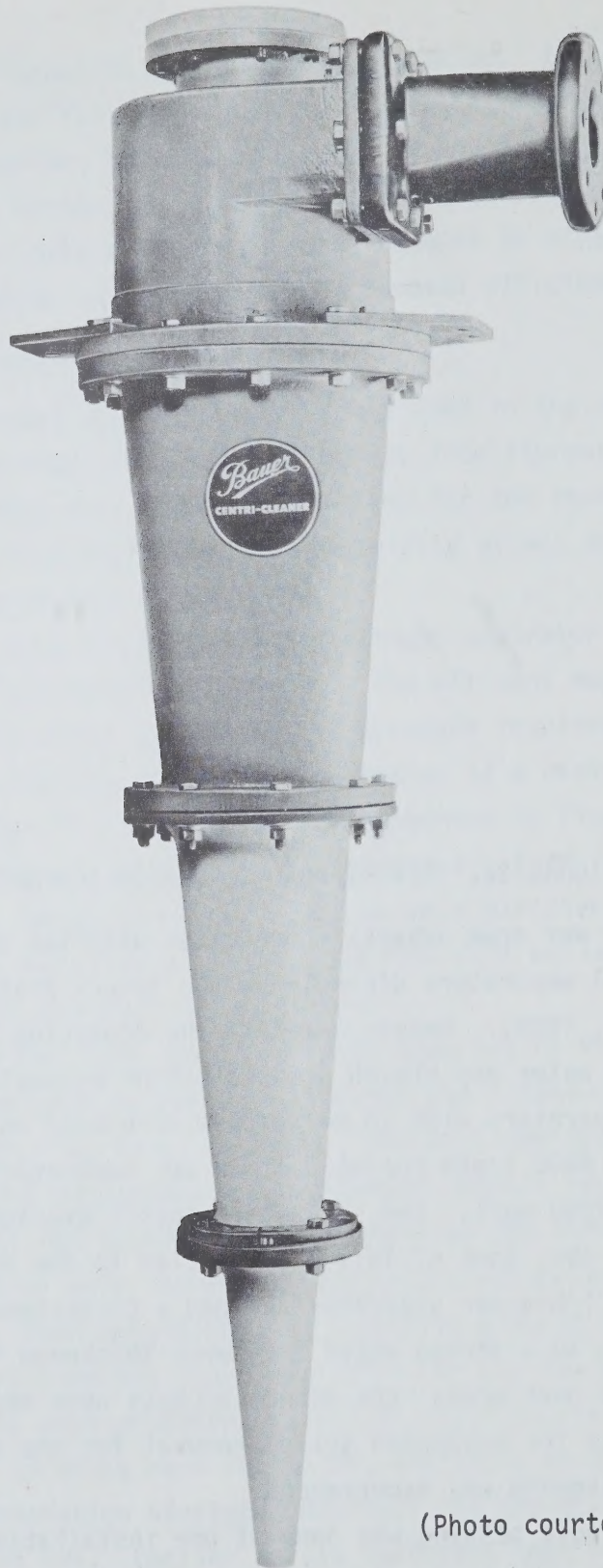


FIGURE 22. CENTRIFUGAL SEPARATOR SCHEMATIC

Another wet drum debarking operation used the same approach in using centrifugal separators directly on the rotary drainer accepts (Ottersen et al., 1969). Makeup water to the debarking drums included paper mill white water and bleach plant alkaline extraction effluent. Four parallel separators with 38 mm nozzles were used on an average effluent flow of 6200 l/min (or 1550 l/min per separator) and a suspended solids level of 2500 mg/l. The separator accepts averaged 1280 mg/l for an efficiency of 49%; some of this was recycled to the drum. The rejects flow averaged 90 l/min per separator and had a consistency of 2.7%. The rejects were sent to a screen where they were thickened to 14% and then discharged to the bark press; the screen accepts were recycled. The overall efficiency for suspended solids removal for the system was 63%. Some separator plugging was experienced.

Considerable testing was done at one installation on wet drum debarker effluent comparing various sizes of centrifugal separators (Lemay et al., 1976). The reject orifice sizes ranged from 11 to 38 mm. It was found that the efficiency of the smaller units was comparable to

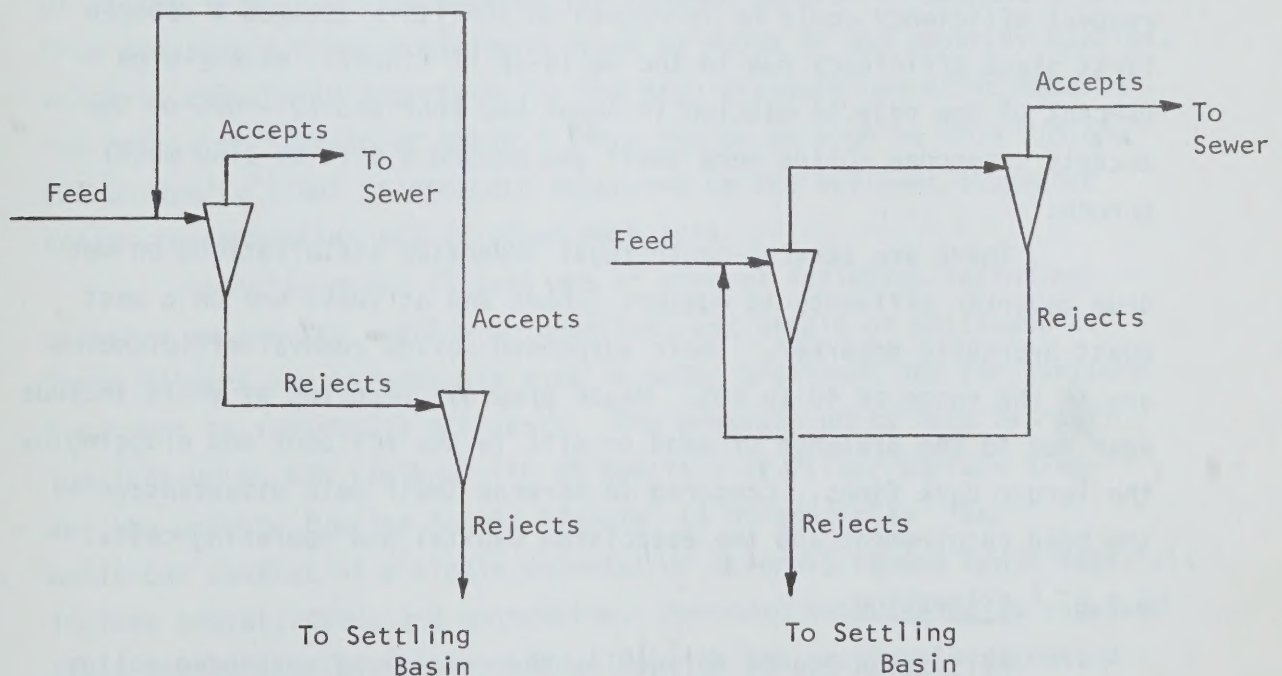


(Photo courtesy of Bauer Bros. Co.)

FIGURE 23. TYPICAL CENTRIFUGAL SEPARATOR

the larger unit at a given pressure drop; efficiencies were 40 to 50% for inlet suspended solids of about 5000 mg/l. However, the larger units had a higher rejects volume and consequent lower consistency. Increased pressure drop, at least within the 205 to 345 kPa (30 to 50 psi) range, did not improve efficiency for the four sizes tested. It was also found that the cleaners were not efficient in removing particles smaller than 0.149 mm (100 mesh).

One equipment supplier reported on pilot trials for plastic centrifugal separators in series on an effluent from a west coast hydraulic debarker processing softwoods of which 70% were hembal and the remainder miscellaneous species that had been screened through a 68 mesh vibrating horizontal screen. The feed suspended solids concentration to the separator was 200 - 250 mg/l. The same model separators were used but different nozzle sizes and two different flow arrangements were investigated. Figure 24 shows the flow schemes tested. When the rejects from the first separator were fed to the second separator (Arrangement 1) with recycle of the second



Arrangement 1

Arrangement 2

FIGURE 24. CENTRIFUGAL SEPARATOR PILOT TEST ARRANGEMENTS

stage accepts to the first stage feed the overall efficiency was about 70%; the first stage accepts having a suspended solids concentration of about 65 mg/l were sewerd and the second stage rejects which had a consistency of about 0.7% were discharged to a settling basin. When the first stage reject nozzle size was increased from 22 to 29 mm the efficiency increased slightly but the rejects volume more than doubled from 12% of the feed to 26%. Also, the separator efficiency was increased and the reject volume decreased slightly if the reject nozzle was submerged and not open to atmosphere. The other arrangement tested was to discharge the first stage accepts to the second stage, sewer the second stage accepts, recycle the second stage rejects to the first stage feed, and discharge the first stage rejects to settling. This scheme provided a slightly higher overall efficiency, 75%, but produced a much higher rejects flow and would require about 25% more separators. It was estimated that if the first scheme was installed and 75% of the first stage accepts were recycled to the debarker, the overall suspended solid removal efficiency could be increased to 78% (this assumed a reduced first stage efficiency due to the build-up of fines). Ninety-nine percent of the rejects settled in about one hour and 70 - 90% of the accepts suspended solids were small and passed a 0.15 mm (150 mesh) screen.

There are several centrifugal separator installations on wet drum debarker effluents in eastern Canada and at least one on a west coast hydraulic debarker. Their suspended solids removal efficiencies are in the range of 40 to 50%. Major problems reported by mills include wear due to the presence of sand or silt in the effluent and plugging by the larger bark fines. Compared to screens their main disadvantage is the head requirement and the associated capital and operating costs.

6.2.5 Filtration

Filtration can be defined as the removal of suspended solids from an effluent by a porous media which can either be fixed (fixed media filters) or loose (such as granular media filters). This discussion is restricted to filters used on effluents with relatively low levels of suspended solids and does not include sludge dewatering filters.

This process is not presently used, at least not to any significant extent, in the treatment of wet debarker effluents but some experimental work has been done for this application, and the low effluent suspended solids concentration produced by this type of equipment may be necessary to meet future effluent requirements or to permit increased effluent recycle. Both fixed and loose media filters are capable of producing effluent suspended solids levels below 50 mg/l.

Fixed media filters are operated under pressure and can be classified into two main groups: those with disposable media and those with permanent media. These filters are generally used for the removal of low suspended solids levels for the protection of specific equipment such as nozzles or the removal of solid contaminants from a process liquid. The disposable media are usually the cartridge type of natural or synthetic fibre. The permanent media filter is usually constructed of a material such as stainless steel that can be backwashed, either manually or automatically as required. The most likely application for this type of filter is as a polishing step for further removal of suspended solids from previously treated effluent prior to reuse in the debarker nozzles, which is especially important for the high pressure hydraulic debarker. The hydraulic loading of these filters can be as high as 1000 l/min/m^2 (25 US gpm/ft^2) but is directly dependent on the influent suspended solids concentration and is often much less.

Granular media filters are of several varieties including: pressure or gravity, upflow or downflow, and single or multi-media. These filters are extensively used in water treatment and for tertiary treatment of industrial effluents. The pressure units have hydraulic loadings up to 400 l/min/m^2 (10 US gpm/ft^2) of filter surface area and the gravity type up to 160 l/min/m^2 (4 US gpm/ft^2). The media can consist of a single material or several; common media materials include gravel, sand, and anthracite. Periodic backwashing is required since the media plugs with solids. As with the previously discussed fixed media filters the granular media filters would be restricted to use as a polishing step on previously treated effluent in order to minimize plugging and be economically viable.

6.2.6 Biological treatment

Biological treatment of wet debarker effluents is not presently common practice either because regulations have not required it or the debarker effluent is treated with other mill effluents. Biological treatment may be required, however, as permitted effluent BOD levels are reduced and/or toxicity removal is required.

Laboratory tests treating various debarker effluents with a five-day aerated lagoon and 24-hour activated sludge found that more than 80% of the BOD₅ was removed (B.C. Research, 1976). The primary purpose of these tests was to determine if biological treatment would reduce the toxicity of debarker effluents and the conclusion was that it was only partially successful. Later studies (B.C. Research, 1976), however, verified the biodegradability of wood derived toxicants and concluded that both a five-day aerated lagoon and six-hour activated sludge would completely detoxify such effluents.

Hoffbuhr et al (1971) found that 80% of the BOD₅ and 50% of the COD was removed from log pond waters (which are similar to debarker effluents) after one day of aeration. From these and other results it was concluded that most biodegradable organic matter can be removed by an extended aeration system with a retention time of one to five days.

As far as colour reduction is concerned, it can be expected that as with pulping effluents, the colour will not be appreciably reduced by biological treatment.

6.2.7 Other treatment methods

This section discusses several physical-chemical treatment methods under the headings of specific debarker effluent characteristics.

pH control. The control of debarker effluent pH may be required as the soluble organic acids fraction of the wood extractives tends to depress the pH; this is particularly true in recycle systems where the level of extractives is relatively high. It is not necessary, however, to fully neutralize the pH as a level in the range of 6.0 to 6.5 is usually adequate to minimize corrosion; also, if alum is to be used as a coagulant in the treatment process, a slightly acidic pH provides optimum alum effectiveness. Furthermore, the lower pH is the ideal range for many biocides if

required for slime control. Neutralization is usually achieved by the addition of caustic soda or one of the various forms of lime available. Where debarker effluents are mixed with other effluents that are alkaline, treatment may not be required.

Slime control. Biological growth in the form of slime can be a problem in debarker effluents due to equipment plugging. Most installations use periodic mechanical cleaning methods such as high pressure hoses to detach the slime. Biocides applied to the effluent can also be used. One U.S. mill hydraulically debarking redwood and employing a high recycle rate, used continuous chlorine application to prevent slime build-up in the system; this may not be practical in non-recycle systems as a chlorine residual must be maintained and therefore large quantities of chlorine would be required. Another method that can be applied to specific pieces of equipment, such as screens, to prevent slime growth is the use of ultraviolet light shining on the affected surface.

Colour reduction. The colour of debarker effluents can be significant as previously discussed. Although there are no treatment systems for colour reduction specifically on debarker effluents there are a few full scale installations on pulp mill effluents. It is only recently that the impact of coloured effluents on receiving waters has been considered and therefore the technology for its abatement is in its infancy. The primary source of colour from wood handling or pulp operations is lignin or lignin derivatives which are highly resistant to microbial degradation and therefore colour is essentially unaffected by biological treatment. Full scale methods for colour reduction include both alum and lime coagulation - precipitation, and resin absorption. Several other methods including carbon absorption, reverse osmosis, and ultrafiltration have been piloted and found to be quite successful. A new method using acid and fly ash is currently under investigation at the University of Saskatchewan. The biggest drawback of these techniques is the high capital and operating costs. For this reason it is expected that if colour regulations are developed for debarker effluents, mills will either eliminate wet debarking, elect high recycle rates, or where

applicable treat the debarker effluent with other effluents. Some of these methods, such as carbon absorption are also capable of reducing toxicity and therefore could serve a dual purpose.

A study (Cambrian, 1976) discussed in Section 5.5, found that oxidation of a debarker effluent helped to agglomerate colloidal particles that would settle, thereby reducing the suspended solids as well as the colour. It was observed that oxidation of effluent samples resulted in the water turning a dark blue colour, apparently due to the oxidation and agglomeration of colloidal particles which then settled. If these observations are valid it means that simple aeration of the effluent prior to clarification could provide increased suspended solids removal as well as colour reduction; further study is required to confirm this and to evaluate the potential as a debarker effluent treatment method.

Sludge handling. Because suspended solids removal is associated with almost all wet debarker installations, sludge handling (i.e. dewatering and disposal) is an important consideration. The chosen method of sludge handling depends on the nature of the solids, the type of treatment method that produced the sludge, and the site economics.

The nature of the sludge solids will be determined mostly by the quantity of inorganic material present; this in turn will depend on the method of log transport and handling. If the sludge is high in inorganics, for example, landfilling may be necessary because the sludge would be relatively low in combustibles and the sand may cause abrasion in the incinerator or boiler.

The type of treatment method will determine the consistency of the sludge and therefore whether dewatering is required and if so, the appropriate method. For example, settled sludge from a clarifier will have a consistency in the range of 1 to 5% O.D. solids and will require considerable dewatering for economic hauling or combustion. Bark fines sludge from screens usually has a greater consistency, often more than 10%, and as a result is usually not dewatered further prior to disposal or pressing with the bark for hog fuel.

Mills with settling basins generally do not attempt to dewater the periodically removed sludge but remove it directly to landfill.

Site economics, especially fuel cost and distance to and cost of the landfill site, will determine whether land disposal is a viable alternative to incineration.

Sludge dewatering is usually achieved by filtration, centrifugation, pressing, or evaporation. Disposal of sludge to drying beds for evaporation of water is only practical in warm dry climates and is not practiced in Canada.

Filtration is the most common method of dewatering clarifier sludge and this is usually practiced with a vacuum filter (disc or belt) which will produce sludge with consistencies of 15 to 25%. Filter leaf tests (NSCI, 1966) done on debarker effluent clarifier sludge found that the sludge had a high freeness and that the filter loading rate would be 50 to 60 kg of dry solids/hr/m² (10 to 12 lb/hr/ft²). Because of the high freeness it was concluded that bark fines sludge would probably be useful as a conditioner for dewatering low freeness (hydrous) sludges. A survey of U.S. installations found that most used 120 mesh disc filters for bark fines sludge dewatering and claimed that maintenance was low provided the media was steam cleaned once per shift.

Although there are few, if any, centrifuges in North America on bark sludge, there are several in Europe. One equipment supplier reported five installations on bark sludge exclusively plus others on combinations of bark and other sludges. Some use polymers for conditioning and the sludge cake consistency for pure bark sludge installations varied from 23 to 30%. This same supplier reported test results using a solid bowl decanter centrifuge on lagooned bark fines; the feed sludge had a 1% consistency and produced a sludge cake of 30 to 35% with a centrate suspended solids level less than 1000 mg/l. Operating problems were caused by coarse material (larger than 12 mm) that plugged the centrifuge and grit that produced excessive wear; in a permanent installation these materials would have to be removed prior to centrifuging.

Most mills that have bark presses discharge their screened bark fines or clarifier dewatered sludge to the press for further moisture removal in combination with the bark. Some mills, however, still landfill their bark and therefore usually the sludge. But with increasing costs for land, transportation, and energy, incineration for energy

recovery is gaining prominence. Also, a recent study (Econotech, 1976) of wood waste landfills has shown that bark leachates can be relatively polluted with high toxicity, BOD₅, and colour, and low pH.

Potential alternatives for bark sludge (and other wood wastes) disposal besides landfill and incineration include composting, use as a soil additive or mulch, and pyrolysis. Pyrolysis is the chemical breakdown of a material by heat, usually in the absence of oxygen. It produces methane which can be used as a fuel and bark char which can be used for producing activated carbon, which in turn can be used for effluent treatment (the use of activated carbon produced from bark char for this purpose was investigated by MacDonald and Nguyen (1974)). Although these alternatives are not currently widespread they may realize wider use as the economics change.

6.3 Treatment Systems

6.3.1 General

There are no "package treatment systems" as such for the treatment of debarker effluents and there are almost as many treatment schemes as there are wet debarker installations. The variety of existing systems and the variability of suspended solids removal efficiencies for similar pieces of equipment at different installations indicates the uniqueness of each situation. To extrapolate equipment success or failure from one mill to another is usually not practical and any system design should be based on site conditions and tests. In sections 6.3.2 and 6.3.3 existing full scale treatment systems are discussed for hydraulic and wet drum debarker effluents, respectively.

6.3.2 Hydraulic debarkers

Hydraulic debarkers are found almost exclusively on the west coast in B.C. and the United States, where there are few, if any, wet drum debarkers; in fact all wet debarkers in B.C. are hydraulic. Although hydraulic debarkers are used to debark a variety of species, cedar is the most common because it is difficult to debark mechanically due to the stringy bark and flared butts of the larger logs. Because of the mild climate hot water for thawing is not required so normally all the effluent

originates at the high pressure debarker nozzles, although there may be small volumes of cooling or washdown water included. Also, because of the high pressure operation, fresh water that is low in suspended solids is used and it can therefore be assumed that all pollutants originate at the debarker. Most treatment systems consist of screening (usually of the vibrating horizontal type) and sedimentation (usually clarifiers or settling basins); some of the U.S. clarifier installations use coagulants to improve suspended solids removal. The sludge from the clarifiers is continuously removed and dewatered and usually used as hog fuel. Settling basins are generally cleaned three or four times per year depending on the size, and the sludge disposed of to landfill. Table 26 shows the extent of hydraulic debarker use and effluent treatment at 22 B.C. pulp mills. Of the almost 300 sawmills in B.C. there are only about a dozen with hydraulic debarking. Most of these have screens on the effluent for bark fines removal and about half also use sedimentation; two successfully recycle their effluent. Some mills in B.C. have converted or plan to convert to dry debarking in order to eliminate the effluent problem. Descriptions of several hydraulic debarker effluent treatment systems follow.

Mill 11

Mill 11 as discussed in section 3.6, is a Canadian west coast sawmill which debarks about $40 \text{ m}^3/\text{hr}$ (14 cunits/hr) of cedar with a Bellingham hydraulic debarker. All wood is water driven and sorted. The effluent is totally recycled with a fresh water makeup of about 25%. The reason for the makeup is that there are no bark press or sludge dewatering facilities on the site and all wood waste is removed wet. The mill is located on a river and, as discussed in section 6.1.2, if it did have an effluent would have to meet more stringent objectives than installations with marine discharges such as Mill 12.

The effluent treatment system is shown in Figure 25. Effluent from the debarker flows by gravity to a cylindrical rotary screen with a 1.41 mm opening (12 mesh) stainless steel screen. The screen is 3.7 m long by 1.2 m in diameter and set at an angle of about 10° to the horizontal, and operates essentially the same as a rotary drainer. The

TABLE 26. B.C. PULP MILL DEBARKING SUMMARY

Debarking Description	Number of Mills	Number of Mills with Effluent Treatment		
		None	Screening	Sedimentation
Totally Wet*	7	0	6	4
Partially Wet*	5	0	5	1
Totally Dry	4	4	-	-
No Debarking	6	6	-	-
Total	22	10	11	5
				7

*All wet debarkers are of the hydraulic type.

screen filtrate plus a small amount of screen backwash water flows to a sump where approximately 20 l of 50% caustic soda are added per week to maintain a near neutral pH. Without the addition of caustic the pH is reported to reach levels of 3 to 4. The effluent is pumped from the sump to the primary settling tank which is 3 m in diameter and 6 m high, yielding a theoretical residence time of about 30 minutes. Most sludge settles in this tank. The settled sludge is automatically pumped from the tank about once per hour. It is removed from the site wet along with other wood waste. Overflow from this tank gravitates to the secondary settling tank which is the same size as the primary. Sludge accumulation in this tank is much less than in the primary tank and is pumped out periodically by manual control. Makeup water to the system is by level control to this tank from the river and is about 25% of the total debarker requirement. Clarified effluent is pumped from about the 75% level of the secondary settling tank by a booster pump to the high pressure stainless steel debarker pump. A strainer on the high pressure pump suction protects the pump from non-settled solids and has to be manually cleaned once or twice per day.

When total recycle was first instigated wear rates on the debarker nozzles and the high pressure pump increased considerably. However, since installing carbide tip nozzles on the debarker and replacing the high pressure pump wetted parts with stainless steel, wear rates have been reduced to pre-recycle levels. Other effects due to recycle include the reduced pH, which as been rectified by the addition of caustic, and periodic fogging in the debarker due to the increased water temperature.

The interesting aspect of this effluent recycle system is that it was designed and built in-house for about \$34,000 in 1974.

Mill 12

Mill 12 is a Canadian west coast sawmill with two hydraulic debarkers processing cedar and hemlock at a rate of about 240 m³/hr (85 cunits/hr). The debarkers are a Bellingham and a 36" Hansel ring. A diagram of the system is shown in Figure 26. All wood is water driven and sorted.

Filtered lake water is used as debarker water supply. Both debarkers use about the same amount of water but because of the limited

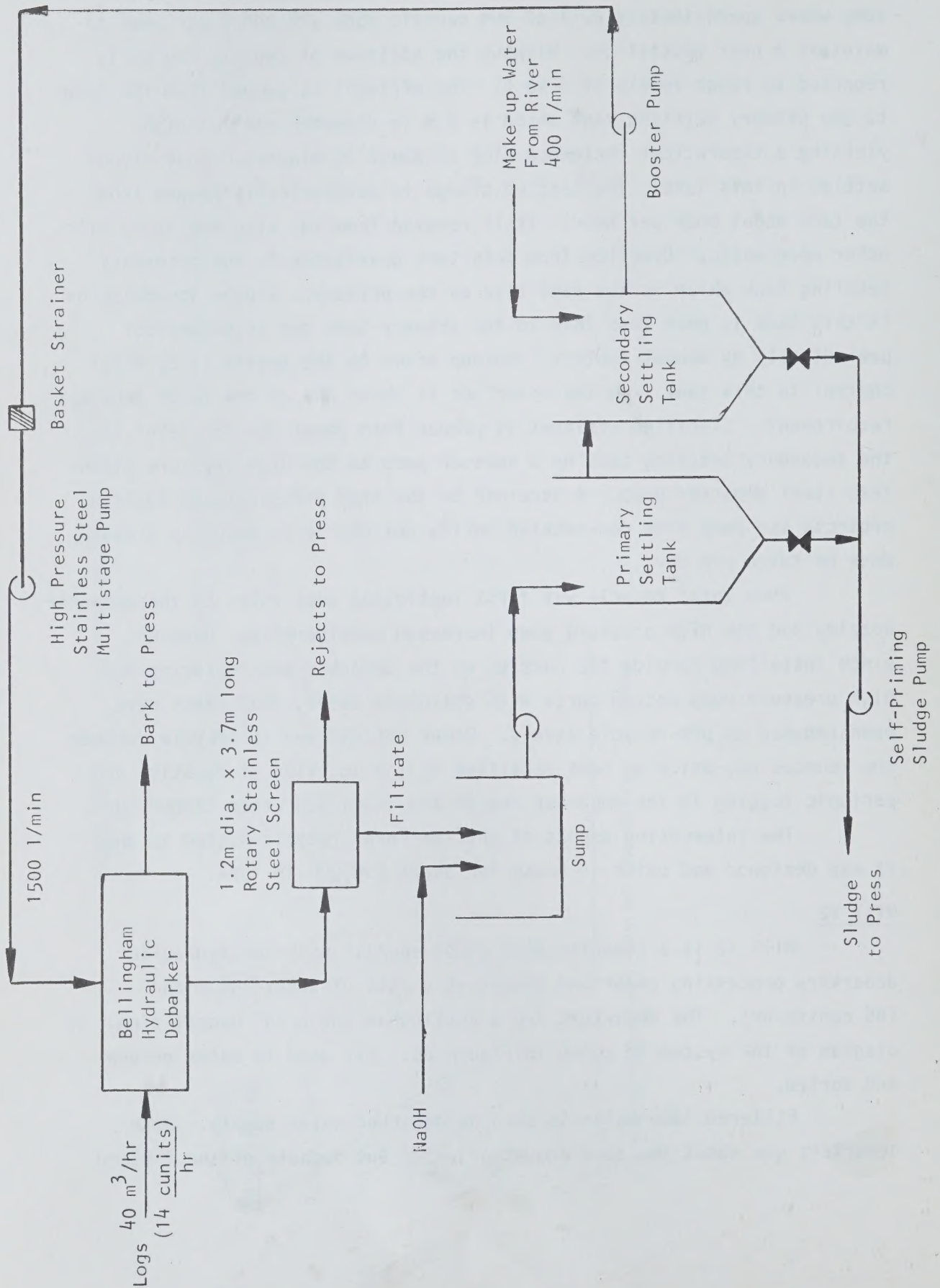


FIGURE 25. MILL 11 EFFLUENT TREATMENT SYSTEM

diameter of log processed by the ring debarker, the water usage per volume of wood debarked is about twice that of the Bellingham. The effluent from the Bellingham flows over three 1.2 by 2.4 m, 100 mesh (0.149 mm opening) horizontal vibrating screens which remove much of the bark fines. These screens have required considerable maintenance due to plugging and breakage of the mesh as well as structural problems. The screened effluent is pumped to a 24 m (80 ft) diameter centre feed, centre drive clarifier with a 3 m (10 ft) sidewall depth, two sludge rakes, and two surface skimmers. The effluent from the ring debarker flows over a 1.2 by 2.4 m horizontal vibrating screen (mesh size not known), which requires little maintenance and is apparently sturdier than the screens used on the Bellingham effluent. It is then pumped to the common clarifier feed line. The clarifier hydraulic loading rate is 24 l/min/m^2 (0.6 US gpm/ft^2) and has a residence time of about two hours. The sludge from the clarifier is pumped by two diaphragm pumps to a three-disc vacuum filter. The filter requires considerable maintenance due to plugging and breakage of the nylon medium. The filter bark fines sludge which has a consistency of about 25% is sent to the pulp mill hog fuel after pressing. The filtrate is returned to the clarifier feedwell. Slime buildup on the screens and other equipment has been a periodic problem that is currently rectified by purging with high pressure water.

The clarifier efficiency in removing suspended solids averages 82%. It produces an effluent with an average total suspended solids concentration of 80 mg/l and a loading of about 0.24 kg/m^3 (1.5 lb/cunit) of wood debarked which is the B.C. Level A objective. The average effluent BOD_5 concentration of 124 mg/l and loading of 0.37 kg/m^3 (2.3 lb/cunit) meets the old B.C. objective of 0.40 kg/m^3 (2.5 lb/cunit) but not the draft revised objective of 0.18 kg/m^3 (1.1 lb/cunit). The BOD_5 is essentially unchanged across the clarifier, indicating that all the BOD_5 is dissolved or at least colloidal in nature. The average effluent pH is 6.7 with a low of 6.3. Effluent data are presented in Table 27.

The total horsepower of the effluent system including screens, pumps, conveyors, filter and clarifier is about 60 hp. Manpower requirements are about eight man-hours per 24 hour operating period and

TABLE 27. MILL 12 EFFLUENT DATA

<u>Parameter</u>	<u>Number of Samples</u>	<u>Units</u>	<u>Data Description</u>	<u>Clarifier Influent</u>	<u>Clarifier Effluent</u>	<u>Removal Efficiency (%)</u>
TSS	22	mg/l	concentration range	79-1710	28-145	82
		mg/l	average concentration	452	80	
		kg/m ³	average loading	1.30	0.24	
BOD ₅	17	mg/l	concentration range	8-375	15-280	1.6
		mg/l	average concentration	126	124	
		kg/m ³	average loading	0.37	0.37	
pH	18	-	range	6.1-7.2	6.3-7.1	
		-	average	6.6	6.7	

are mainly required for maintenance. Material costs for equipment parts are about \$500/month.

Mill 13

Mill 13 is a west coast mill with a three-arm Hansel hydraulic debarker processing water driven and sorted fir and hembal at 210^3 /hr (75 cunits/hr). The treatment system consists of horizontal vibrating screens and two six-hour settling basins in series as shown in Figure 27. Fresh water usage by the debarker is about 7100 l/min (1875 US gpm) or 2000 l/m^3 (1500 US gal/cunit) of wood processed. Water from the debarker is screened on three parallel 1.2 x 2.4 m horizontal vibrating screens with 1.6 mm openings (~ 10 mesh). Screen rejects are pressed prior to use as hog fuel. Screened effluent is then pumped to two series-oriented six-hour settling basins. Effluent from the second basin is discharged to a marine receiving water. The settling basins are dredged approximately every three months and the sludge landfilled.

A summary of effluent data based on daily composite samples, is shown in Table 28. Floatable solids are also measured but are almost always nil. As the data indicate the ponds are about 97% efficient in the removal of suspended solids yielding an average effluent suspended solids concentration of 48 mg/l and a loading of 0.10 kg/m^3 (0.6 lb/cunit) of wood debarked, which is considerably less than the 1.5 lb/cunit B.C. objective. About 36% of the BOD_5 is removed across the ponds yielding an effluent loading of 0.16 kg/m^3 (1.0 lb/cunit), also lower than the objective of 1.1 lb/cunit. The effluent is fairly toxic, and consistently fails to meet the minimum 96-hour LC_{50} Level A objective. On one occasion when both pond inlet and outlet samples were taken, toxicity was greater at the pond outlet suggesting that toxicants were being leached from the accumulated sludge; this may be a major disadvantage of long residence time settling basins compared to clarifiers or other methods where the fines and water contact time is considerably less.

Mill 14

Mill 14 is a west coast sawmill debarking cedar with a two-arm Nicholson hydraulic; the processing rate is about 57 m^3 /hr (20 cunits/hr).

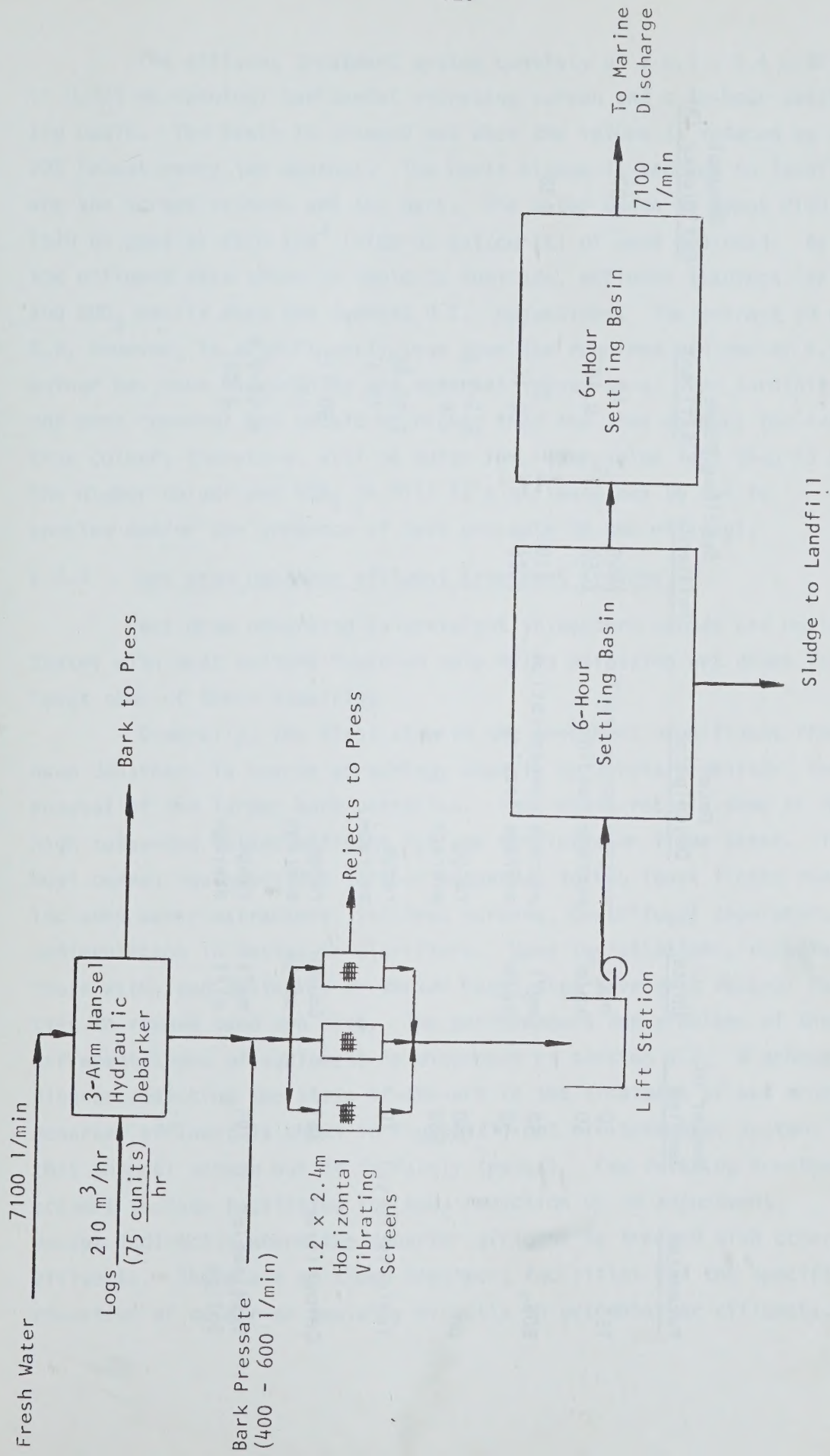


FIGURE 27. MILL 13 EFFLUENT TREATMENT SYSTEM

TABLE 28. MILL 13 EFFLUENT DATA

<u>Parameter</u>	<u>Number of Samples</u>	<u>Units</u>	<u>Data Description</u>	<u>Settling Ponds Influent</u>	<u>Settling Ponds Effluent</u>	<u>Removal Efficiency (%)</u>
TSS	50 50	mg/l kg/m ³	average concentration average loading	1469 2.60	48 0.10	97
BOD ₅	50 50	mg/l kg/m ³	average concentration average loading	118 0.26	76 0.16	36
pH	580 580	- -	range average		5.8-7.2 6.6	
Toxicity (LC ₅₀)	10	%	range average		1.25-45 19.3	
Colour (true)	261	Colour units	range average		50-875 136	
Settleable Solids	305	ml/l ml/l	range average		0.01-0.9 0.02	

The effluent treatment system consists of a 0.9 x 2.4 m 40 mesh (~ 0.373 mm opening) horizontal vibrating screen and a 10-hour settling basin. The basin is cleaned out when the volume is reduced by about 20% (about every two months). The basin sludge is trucked to landfill as are the screen rejects and the bark. The water usage is about 2160 l/min (570 US gpm) or 2270 l/m³ (1700 US gal/cunit) of wood debarked. As the effluent data shown in Table 29 indicate, effluent loadings for TSS and BOD₅ easily meet the current B.C. objectives. The average pH of 5.9, however, is significantly less than the required minimum of 6.5. The colour has been measured as the apparent colour (i.e. the turbidity has not been removed) and should be higher than the true colour; the average true colour, therefore, will be quite low, some value less than 43 units. The higher colour and BOD₅ in Mill 13's effluent may be due to species and/or the presence of bark pressate in the effluent.

6.3.3 Wet drum debarker effluent treatment systems

Wet drum debarking is prevalent in eastern Canada and United States with most eastern Canadian pulp mills utilizing wet drums for at least some of their debarking.

Generally, the first step in the treatment of effluent from wet drum debarkers is coarse screening, usually by a rotary drainer, for the removal of the larger bark particles. Some mills recycle some of this high suspended solids effluent for use as sluice or flume water. The most common equipment for further suspended solids (bark fines) removal includes water extractors, inclined screens, centrifugal separators and sedimentation in basins or clarifiers. Many installations, especially those with land delivered or sorted logs, also have grit removal facilities to remove sand and dirt. The performances and problems of these different types of equipment is discussed in section 6.2. A schematic diagram depicting the state-of-the-art in the treatment of wet drum debarker effluent is shown in Figure 29; not all treatment systems follow this general scheme but it is fairly typical. Few existing treatment schemes include facilities for BOD₅ reduction or pH adjustment, except indirectly where the debarker effluent is treated with other mill effluents. There are no known treatment facilities for the specific reduction of colour or toxicity directly on wet debarker effluents.

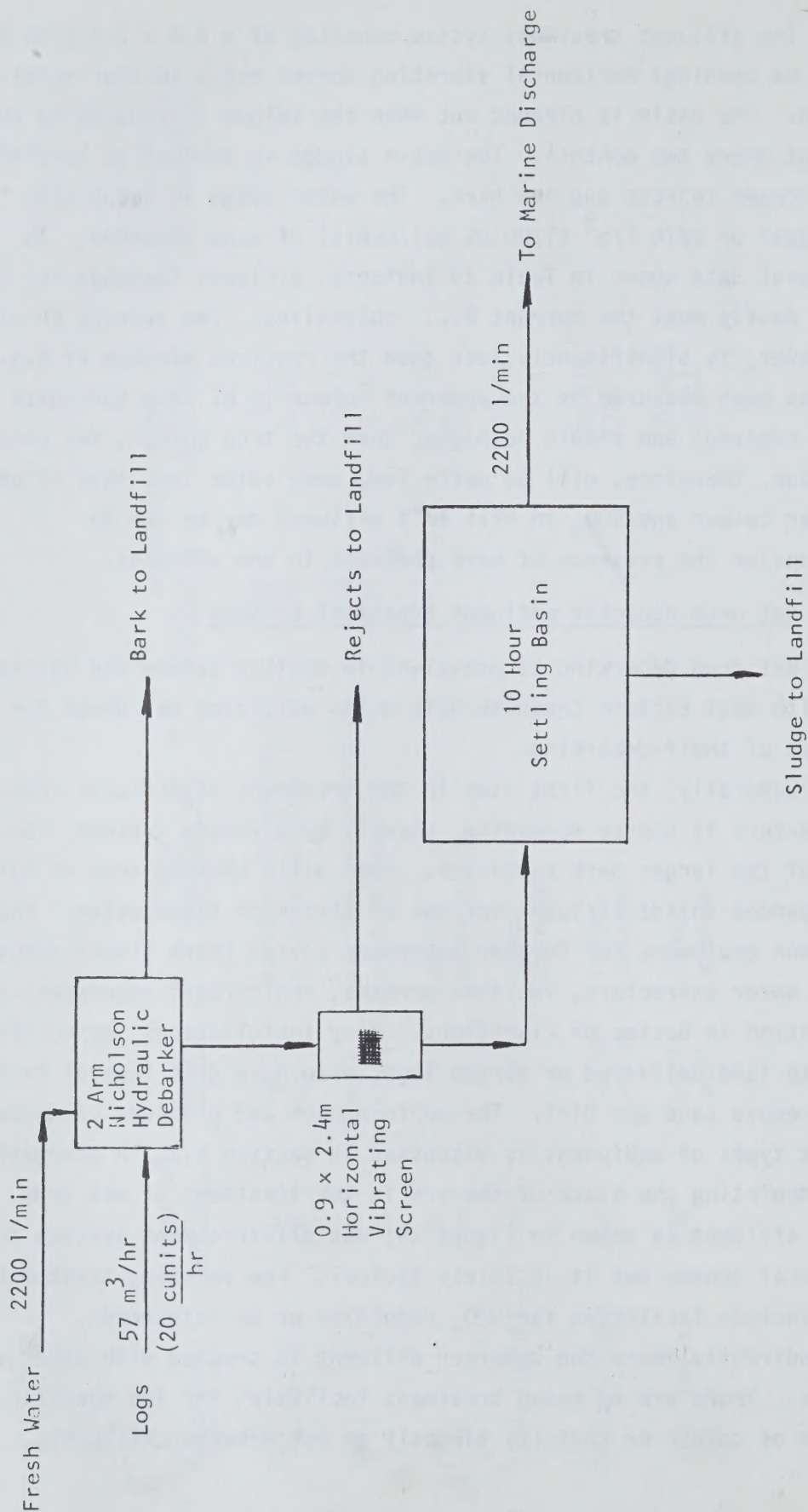


FIGURE 28. MILL 14 EFFLUENT TREATMENT SYSTEM

TABLE 29. MILL 14 EFFLUENT DATA

<u>Parameter</u>	<u>Number of Samples</u>	<u>Units</u>	<u>Data Description</u>	<u>Settling Pond Effluent</u>
TSS	48	mg/l mg/l kg/m ³	concentration range average concentration average loading	1-214 42 0.1
BOD ₅	14	mg/l mg/l kg/m ³	concentration range average concentration average loading	0-47 19 0.04
pH	48	- -	range average	3.1-8.7 5.9
Colour (apparent)	41	Colour units	range average	<10-150 43

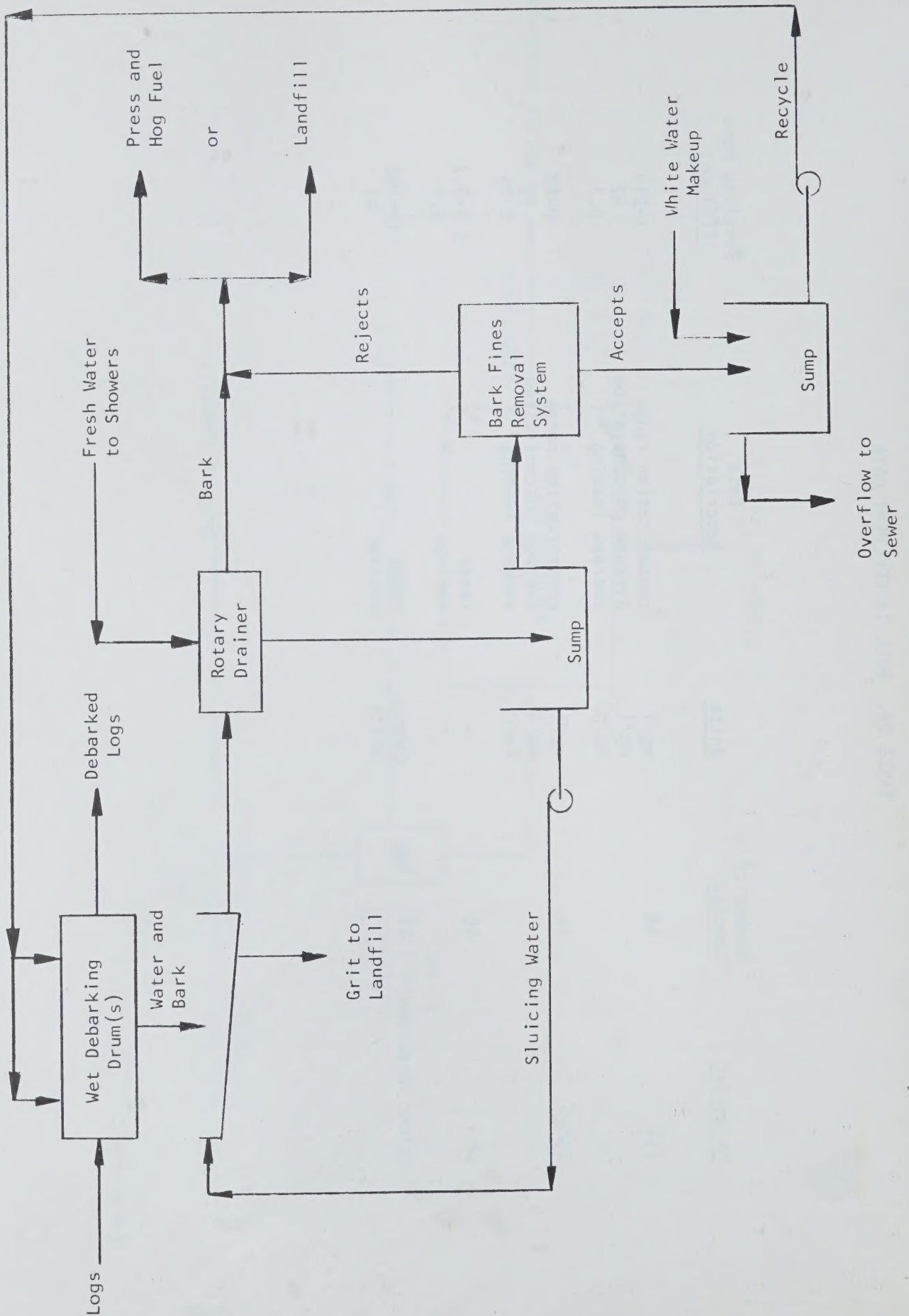


FIGURE 29. TYPICAL WET DRUM DEBARKER EFFLUENT TREATMENT

Water usage in terms of quantity and process locale depends on several variables as discussed in section 5.1. Water uses include shower water before and after the drum, log sluicing, log storage, and backflush for drainers and screens. Makeup water usually consists of fresh water and other mill effluents such as caustic extract or white water. The mill effluents are used to add heat and reduce fresh water usage; during the winter the ratio of warm effluent usage to fresh water is usually increased to facilitate thawing of frozen logs. Consequently, during the winter the effluent flow and pollutant loadings may be somewhat greater. The use of these other mill effluents results in highly variable debarker effluent characteristics from mill to mill and even within a given installation. Many mills practice at least some recycle of the clarified debarker effluent back to the debarker showers.

Most installations use their wood waste for hog fuel and therefore rejects from screens and centrifugal separators are usually conveyed to a bark press along with the bark.

Mill 15

Mill 15 is an eastern Canadian pulp mill using two 3.7 m diameter by 13.7 m long wet drums for debarking truck balsam and spruce. The debarking rate averages about $42 \text{ m}^3/\text{hr}$ (15 cunits/hr). The effluent treatment system is shown in Figure 30. Water usage is about 7700 l/m^3 of wood debarked but only a small amount of this is fresh water as some effluent is recycled and also paper mill white water and pulp mill centricleaner rejects are used as makeup. A portion of the drainer flow (not shown in Figure 30) is recirculated at a rate of about 7000 l/min for use as sluicing water between the drums and bark drainer.

Effluent discharged to the river has a suspended solids concentration of approximately 450 mg/l or about 1.3 kg/m^3 (8 lb/cunit) of wood debarked; BOD_5 levels are 3.1 kg/m^3 (19 lb/cunit). These values are in the range of 4 and 9 kg/tonne of dry wood, respectively, depending on wood species, in which case the TSS loading currently meets the proposed Quebec regulations but the BOD_5 does not. The effluent pH is quite low at 4.8 to 5.2 and also does not meet the proposed minimum limit of 5.5. One bioassay on the woodroom effluent had a 96-hour LC_{50} 5.6%.

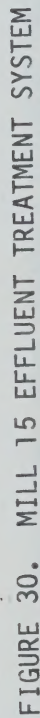


FIGURE 30. MILL 15 EFFLUENT TREATMENT SYSTEM

The efficiencies of the water extractors and centrifugal separators are considerably lower than those reported at other installations, about 15 and 25%, respectively. This may be due to a high effluent fines content as a result of the white water make-up and effluent recycle; however, it demonstrates the variability of equipment performance from one installation to another.

Problems with the system include equipment wear due to sand and grit and water extractor blinding due to pitch and bark fines.

Mill 16

Mill 16 is an eastern Canadian pulp mill wet drum debarking 55% spruce, 30% balsam, and 15% Jack pine. The wood is transported to the mill by river and trucks, about two-thirds and one-third, respectively. Summer processing rates are about $56 \text{ m}^3/\text{hr}$ (20 cunits/hr) per drum, and slightly less in winter because more of the wood is land transported and consequently has more bark coverage; also, logs are often frozen.

The effluent treatment system is shown in Figure 31. Effluent and bark from the debarker flows to a 1.5 m diameter by 7.3 m long rotary drainer with 5 mm holes. The recovered bark is sent to a bark press and the effluent flows to three parallel triple screw water extractors for removal of bark fines. Rejects from the extractors, which have a consistency ranging between 10 and 15%, are sent to the bark press and then hog fuel along with the bark. The bark pressate is returned to the water extractors. The moisture content of the wood from the bark press is quite variable and the mill has found, for example, that balsam bark tends to retain water more than spruce bark and therefore yields a wetter hog fuel. The maintenance requirements of the water extractors is high due to sand wear and some pitch plugging; the upstream sand trap tends to fill quickly with heavy bark and therefore does not provide adequate capacity for sand removal. Large sand particles tend to plug the extractor holes and sand in general causes wear especially of the brushes which must be replaced approximately once per month. The brushes have to be cleaned at weekly intervals and the screens hosed down every few days to unplug holes of sand and bark fines. The screens are chemically cleaned weekly to remove pitch. Because of the plugging and maintenance the extractor capacity is substantially less than the originally estimated rate of 3800 l/min (1000 US gpm) per barrel. The water extractor accepts

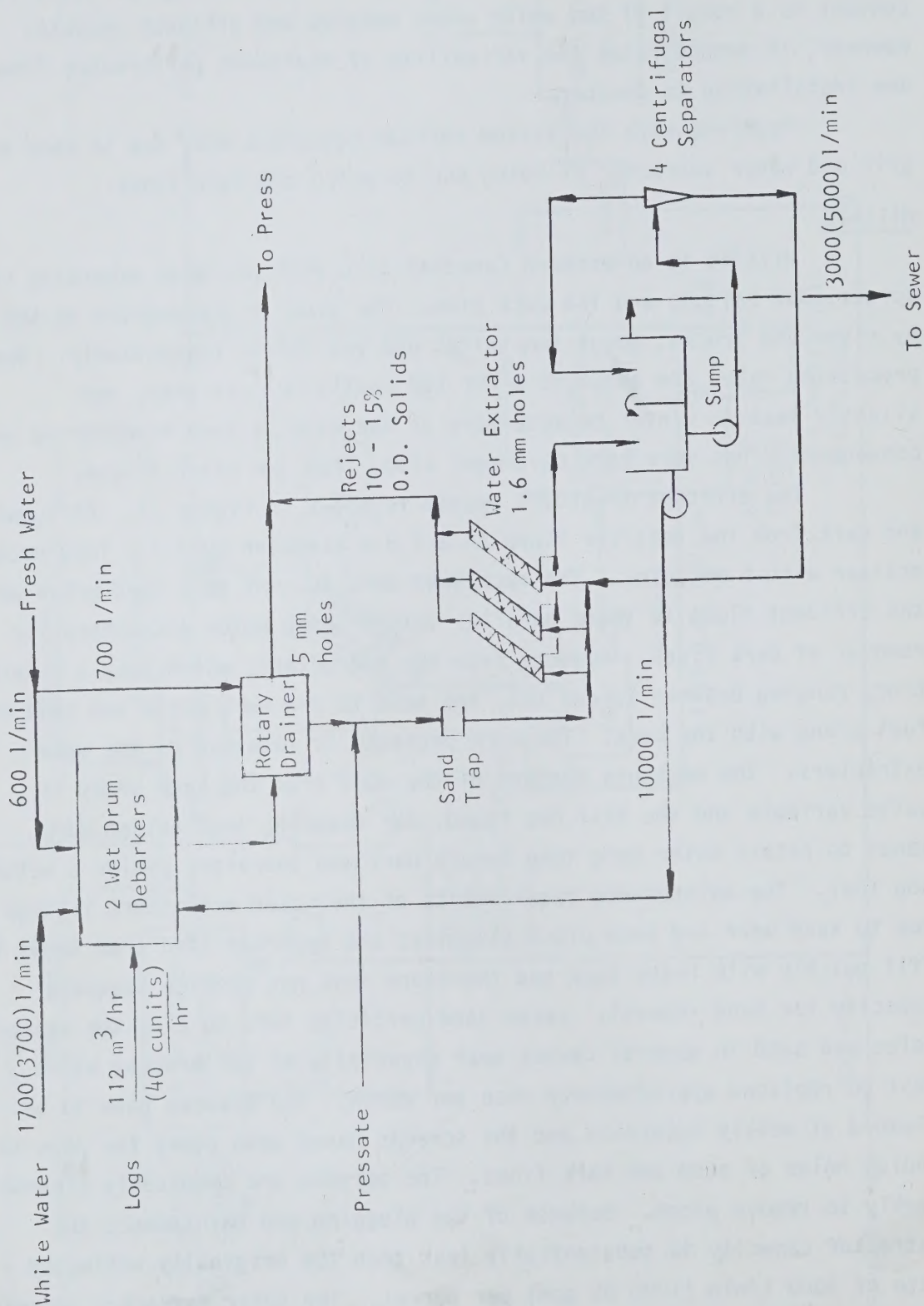


FIGURE 31. MILL 16 EFFLUENT TREATMENT SYSTEM

are partially recycled and the excess pumped to centrifugal separators. These separators experience considerable wear, also due to sand, and last about two years before replacement is necessary. The separator accepts are partially recycled but most are discharged to the sewer; the rejects, which have a consistency of 3 to 5%, are recycled to one of the water extractors for thickening.

Makeup to the system is mostly white water although some fresh water is used as shower water in the drums and in the rotary drainer. Approximately 10,000 l/min of effluent is constantly recycled for use in the flume. The discharged effluent flow rate and suspended solids concentration varies depending on the amount of white makeup; the approximate winter flow rates are shown in parentheses in Figure 31. The average suspended solids loss to the sewer is 3.8 kg/m^3 (24 lb/cunit) of wood debarked; this value will be lower in summer, and greater in winter as the white water makeup increases.

Mill 17

Mill 17 is a pulp and paper mill complex in eastern Canada wet drum debarking mostly spruce and balsam. Most of the logs are land transported. The debarking is carried out in six drums at approximate per drum rates of $42 \text{ m}^3/\text{hr}$ (15 cunits/hr) in the summer and 28 m^3 (10 cunits/hr) in the winter. The effluent treatment system is shown in Figure 32. The effluent from the drums passes through a sand riffler for removal of grit prior to removal of the larger bark pieces on a perforated scraper conveyor. The effluent from the conveyor is discharged to a rotary drainer with 6.4 mm holes for further bark removal; recovered bark from the conveyor and drainer is sent to the bark press prior to use as hog fuel. The accepts from the drainer are pumped to centrifugal separators for further suspended solids removal. The separator accepts are recycled to the debarking drums and the rejects are thickened on two inclined screens that use paper machine wire for the mesh. The inclined screen accepts are routed to the inclined plate clarifier for further clarification prior to discharge to the sewer; the screen rejects are conveyed to the bark press. Poor clarifier performance was originally experienced due to entrained air but this was rectified by installation of a vacuum deaerator on the clarifier feed. The clarifier suspended

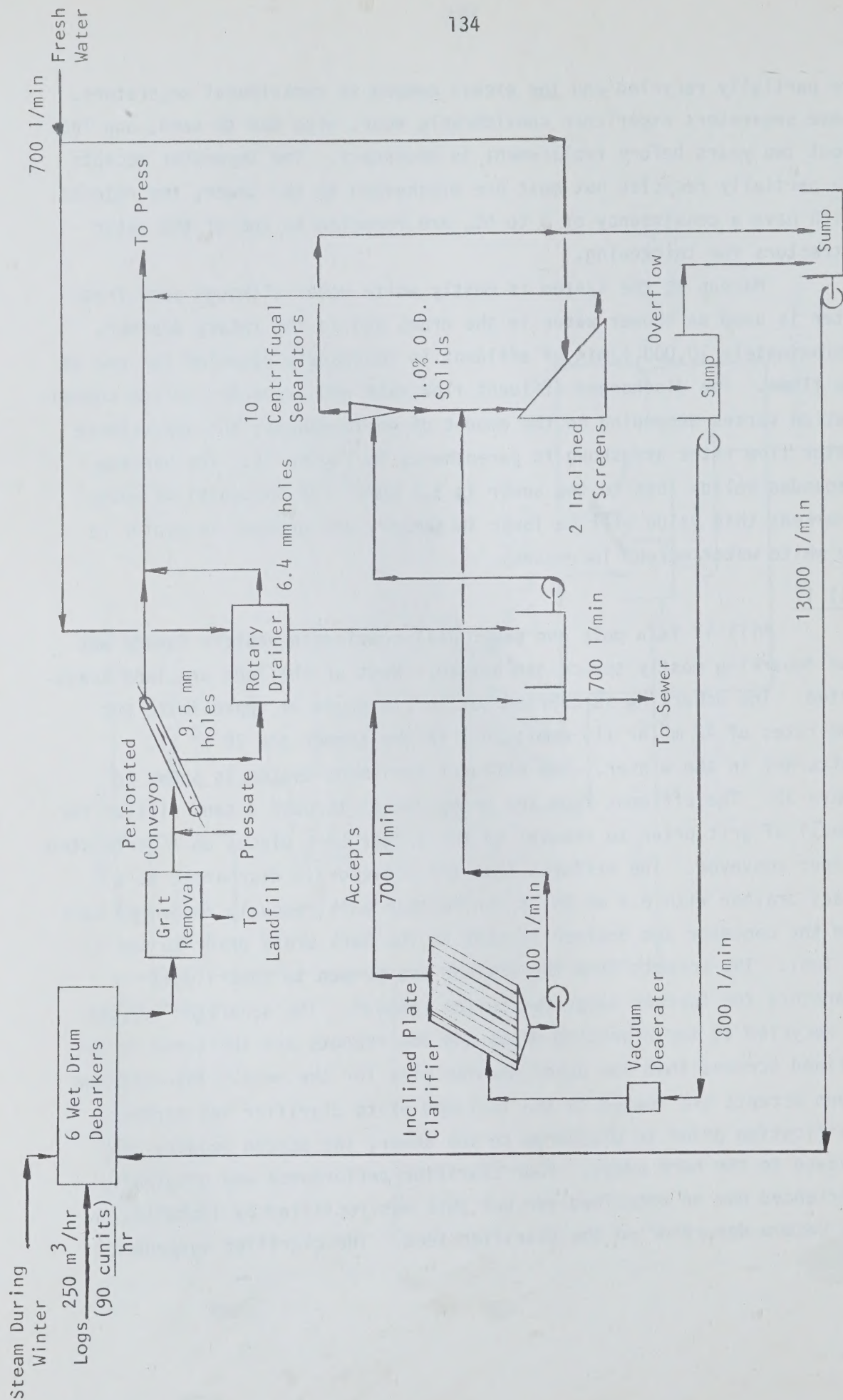


FIGURE 32. MILL 17 EFFLUENT TREATMENT SYSTEM

solids removal efficiency is about 70% at an hydraulic loading of 10 l/min/m², without the use of a flocculant.

Even with the grit removal facilities, wear is still a major problem throughout the system but especially of the centrifugal separators. Another maintenance problem is created by sludge that tends to accumulate between the 50 mm spaced clarifier plates which must be cleaned daily.

The discharged effluent flow rate is about 700 l/min and has the following properties:

	<u>mg/l</u>	<u>Summer Loading Rate (kg/m³)</u>
Total suspended solids	3800	0.6 (3.7 lb/cunit)
Dissolved solids	1200	-
BOD ₅	2000	0.3 (1.9 lb/cunit)
pH	5.2	-

Fresh water makeup is used for shower water on the rotary drainer and inclined to screen. During the winter steam is added to the drums to quicken the log thawing process.

6.4 Future Treatment Considerations

Sections 6.3.2 and 6.3.3 discussed treatment methods and systems currently employed on hydraulic and wet drum debarkers. Few, if any, debarker installations consistently achieve all existing or proposed effluent parameter limits and this situation will certainly deteriorate as regulations become more restrictive and new parameters, such as colour, are added. Consequently, those installations that choose to continue wet debarking will probably be required to provide more sophisticated and costly effluent treatment methods.

When a wet debarking installation is faced with more stringent effluent regulations, there are three alternatives to be considered: convert to dry debarking; install facilities to treat the effluent to the required effluent quality; or install facilities to treat the effluent to the degree required for recycle (either total, or partial recycle with further treatment facilities on the reduced volume of discharged effluent if required).

Some wet debarkers associated with pulp mills have only preliminary treatment for bark removal as the effluent is treated and discharged with other mill effluents. This approach, however, may not be the optimum solution when the effect of the debarker effluent load on the combined treatment system and the benefits of retrieving combustible bark fibre are considered. For this reason or because the debarker effluent is discharged separately, some pulp mills may decide to treat the debarker effluent separately. At sawmill installations, the wet debarker is the primary source of effluent except perhaps for small flow contributions from cooling waters, sanitary effluent and other miscellaneous streams.

It is apparent that for improved suspended solids removal, sedimentation or flotation techniques will have to be applied in lieu of or in conjunction with screening. Most hydraulic debarkers currently employ clarifiers or settling basins but many wet drum debarkers do not. Sedimentation should provide suspended solids removal efficiencies over 70%, and if chemically assisted to enhance coagulation and flocculation, over 90%; the BOD_5 will be partially reduced at the same time and perhaps some of the toxicity and colour. Methods that show promise but are largely unproven on debarker effluents, such as microstraining and filtration, should be considered and investigated.

The extent to which fine screening is applied prior to clarification will depend on a comparison of screening equipment size and costs, clarifier sludge equipment size and costs, and clarifier performance. In other words, if considerable fine screening is performed on the effluent and a large proportion of the bark fines are removed there will be less clarifier sludge and therefore the sludge dewatering equipment can be smaller. However, the sludge will have a higher percentage of fines and may be more difficult to dewater, and the clarifier efficiency will probably be reduced. Conversely an excess of oversize particles in the sludge may cause too thick a cake for conventional vacuum filtration. Also, the finer the mesh, the more operating and maintenance problems that will be experienced with the screening equipment.

The optimum system at a given installation should be determined by appropriate laboratory or pilot studies and detailed cost estimates.

Biological treatment will eventually be required on most wet debarker effluents for the reduction of BOD_5 and/or toxicity. Although

the aerated lagoon and activated sludge systems are the most proven methods for the treatment of wood processing effluents, other techniques such as the rotating biological contactor should be considered.

Colour removal technology as discussed in section 6.2.7 is relatively new and generally unproven on a commercial basis. Also, because it may be some time before effluent colour guidelines are formulated it is difficult to predict what methods will be required. It may be practical to combine present favoured techniques such as alum or lime precipitation with suspended solids removal and therefore an add-on component for colour removal may not be necessary.

The amount of effluent recycle practiced will affect the method of treatment and the size of the equipment. Wet drum debarkers should be able to practice a recycle rate approaching 100%; during the winter, however, because of higher heat levels required to facilitate bark removal a heat exchanger may have to be provided in the recycle line or steam used so that high rates of hot makeup water are not required. Hydraulic debarkers can employ high recycle rates when high suspended solids removal levels are achieved. Recycling of wet debarker effluents, whether wet drum or hydraulic, results in a reduced pH and a potential increase in corrosion and scaling due to the increase in colloidal and dissolved solids. Also, systems recycling effluent when the logs have been transported or stored in salt water increase the risk of stress corrosion due to high chloride concentrations at low pH.

The presence of bark press effluent may have a significant effect on the treatment scheme selection in some cases. Although the bark press effluent has a relatively low flow rate and suspended solids content it may be high in BOD_5 and pitch.

Potential innovative treatment techniques such as that accidentally discovered by Cambrian (1976), and discussed in section 6.2.7, in which it was found that aeration of the effluent prior to clarification improved the suspended solids as well as the colour removal, should be further investigated. The various filtration methods discussed in section 6.2.5 also deserve further attention especially as a polishing step for recycle flows to showers or debarker nozzles.

7. COSTS

7.1 Debarking7.1.1 Capital costs

The installed capital cost breakdown for dry drum, wet drum, mechanical ring and hydraulic debarking systems is summarized in Table 30 and is based on 1977 dollars. This includes debarkers as well as associated equipment and would be of interest to a new mill considering the alternatives of a wet or dry system. The basis of the comparison is the debarking of $240 \text{ m}^3/\text{hr}$ (85 cunits/hr) which would be a typical requirement for a large sawmill or a moderately sized pulp mill. The drum systems are of the tumbling drum type handling wood up to 60 cm (24 in) in diameter. Log treatment facilities have not been included.

TABLE 30. INSTALLED CAPITAL COST FOR DEBARKING SYSTEMS

	Dry Drum (\$)	Wet Drum (\$)	Mechanical Ring (\$)	Hydraulic (\$)
Slasher	360,000	360,000	-	-
Conveyors	595,000	600,000	480,000	650,000
Debarker	1,170,000	1,050,000	285,000	285,000
Pumps and Piping	-	30,000	15,000	50,000
Bark Processing and Effluent Screening	55,000	375,000	55,000	400,000
Electrical	215,000	260,000	125,000	305,000
Structural	<u>580,000</u>	<u>625,000</u>	<u>240,000</u>	<u>300,000</u>
Total	2,975,000	3,300,000	1,200,000	1,990,000

The wet drum system consists of two drums, each 3.7 m (12 ft) diameter by 20.4 m (67 ft) long. The dry drum system is similar with the exception that drum length is increased to 27.5 m (90 ft) to produce the same bark removal efficiency. It is assumed that the hydraulic and mechanical ring systems would be handling larger logs of 30 to 183 cm (12 to 72 in) diameter. One of either type would be required of maximum 183 m (72 in) size to be able to process the largest log size.

Comparison of the total costs indicates that the dry drum system is 10% less than the wet drum system since most of the cost items are similar except for bark pressing and effluent screening. Total costs are similar to those estimated by Hooper (1974) for wet and dry drum debarking. Comparison of the mechanical ring and hydraulic systems indicates that the cost of a mechanical debarking system is about 40% lower mainly because of the elimination of bark presses, conveyors and electrical components.

7.1.2 Operating costs

Operating costs for debarking have been divided into three components: power, operating labour and maintenance, expressed as cost per unit of production. Cost data for each of the mills surveyed are included in Appendix 5 and average values for mechanical ring, hydraulic, and wet and dry drum debarking are summarized in Table 31. The ratio of total operating cost for mechanical to hydraulic to drum debarking is approximately 1:2:3. The range of values is indicative of site specific variations encountered.

Data summarized in Section 3 for mills that had converted from wet to dry debarking confirm this ratio of operating cost for mechanical and hydraulic debarking. Examination of the cost breakdown reveals that the lower cost for mechanical debarking is due to the fact that the power cost is one-eighth and the maintenance cost is one-half that of hydraulic debarking. The higher cost for drum debarking is primarily due to labour costs. Costs have not been differentiated for wet and dry drum debarking since they are similar; labour and power requirements, which comprise 70% of the total operating cost, are the same for wet and dry drums. Also, in this project, mills that had converted from wet to dry drums reported that maintenance requirements were unchanged.

While there is little information in the literature on debarking operating costs, those reported cover a wide range of values. Wiederman (1972) used a general operating cost for debarking of $\$1.27/\text{m}^3$ ($\$3.60/\text{cunit}$) and compared this to a cost of $\$0.14/\text{m}^3$ ($\$0.40/\text{cunit}$) for additional pulp screening and cleaning if debarking was eliminated. Auchter and Horn (1973) also analyzed the savings available if debarking is eliminated and based their calculations on an operating cost for

TABLE 31. SUMMARY OF AVERAGE OPERATING COST FOR DEBARKING

Type of Debarking	Number of Installations	Power (\$/m ³)	Operating Labour (\$/m ³)	Maintenance (Labour and Material and Supplies) (\$/m ³)	Average (\$/m ³)	Total Range (\$/m ³)
Mechanical Ring	4	0.02	0.14	0.11	0.27	(0.12-0.37)
Hydraulic	4	0.16	0.15	0.20	0.51	(0.32-0.66)
Wet or Dry Drum	4	0.08	0.60	0.27	0.95	(0.43-1.46)

debarking of $\$0.47/\text{m}^3$ ($\$1.34/\text{cunit}$) which included labour, maintenance, utilities, depreciation and miscellaneous. Tyler (1969) used an operating cost for drum debarking of $\$0.1/\text{m}^3$ ($\$0.28/\text{cunit}$) which includes power, maintenance and depreciation. Ranhagen (1970) compared operating costs of different debarking methods and came up with a cost for drum debarking of $\$0.15/\text{m}^3$ ($\$0.42/\text{cunit}$) and a cost for mechanical debarking of $\$0.45/\text{m}^3$ ($\$1.30/\text{cunit}$).

7.2 Effluent Treatment

7.2.1 General

Effluent treatment costs for wet debarkers are highly variable and dependent on many parameters including the nature of the effluent, regulatory requirements, and available space for treatment plant components. The nature of the effluent and the main factors affecting it were discussed in some detail in Section 5.1. Applicable government regulations will determine the effluent parameters that must be controlled and to what extent. Although suspended solids, BOD_5 , and pH have been the effluent parameters of prime concern to date, the importance in controlling toxicity and colour, for example, is now recognized and it can be expected that these parameters will have limitations in more jurisdictions in the near future. The available space and value of land will have a bearing on the specific equipment chosen to accomplish a certain task. For example, for sedimentation, a clarifier will have to be used where there is enough available land for a settling basin, or an inclined plate clarifier where there is not enough room for a conventional clarifier; and for biological treatment a high rate system such as the activated sludge process requires considerably less area than an aerated lagoon.

In this section capital and operating costs for several common and potential debarker effluent treatment components are presented. Operating costs include manpower, maintenance, and utilities, but not taxes and insurance, depreciation and interest, and administrative costs. These costs are estimates based, in some cases, on limited data that are presented for information on relative costs and should not be used for costing treatment systems.

7.2.2 Screens

The hydraulic capacities, equipment costs, total installed costs, and annual operating costs for various types of screening equipment are presented in Table 32. The equipment costs are for screen sizes normally used on debarker effluents and may not apply to units that are significantly larger or smaller. The installed costs include electrical costs for all screens except the inclined stationary which does not have a drive, and for the microstrainer the construction of a sump. The total cost of a screen installation will vary for each application depending on the loading rate, which is determined by the effluent characteristics and screen type; appropriate testing should be performed to determine the optimum screen type and size for a given application.

It should also be noted that although the microstrainer has a lower hydraulic capacity and higher unit area cost than the other screens it also has the capability of significantly higher suspended solids removal efficiencies as discussed in section 6.2.1, and according to Envirocon (1976) has the potential to outperform the clarifier in the removal of suspended bark fines.

Annual operating costs are based on estimates for power, maintenance, and operator attention. Maintenance and manpower costs are guesses at best and will depend on the characteristics of the screen and the effluent.

7.2.3 Centrifugal separators

Centrifugal separator costs vary depending on size and materials of construction, and for units with capacities in the range of 500 to 2000 l/min and having a lower cone of ceramic for minimum wear, the equipment cost is about \$1.00 to \$1.25 per l/min of throughput. For a system of separators handling a wet debarker effluent flow of 5000 - 6000 l/min the total installed costs including separators, feed pump, connecting piping, electrical, and foundations is \$4.00 to \$5.00 per l/min of throughput.

7.2.4 Sedimentation and flotation

Equipment costs, total installed costs, and projected operating costs for three types of clarifiers and a flotation system are

TABLE 32. SCREEN COSTS

<u>Screen Type</u>	<u>Capacity</u>	<u>Cost Basis Size</u>	<u>Equipment Cost</u>	<u>Total Installed Cost</u>	<u>Annual Operating Cost (\$)</u>
Vibrating Horizontal	800-1600 l/min/m ² *	3-5 m ²	2500-3500 \$/m ²	4300-5300 \$/m ²	2500-3000
Inclined Stationary	600-1000 l/min/m	1.5 - 1.8 m	4000-5000 \$/m	4800-5800 \$/m	2000-2500
Rotostrainer	600-1200 l/min/m ²	4-8 m ²	4500-6000 \$/m ²	6300-7800 \$/m ²	2500-3000
Water Extractor	6000-10000 l/min/unit**	-	20000-25000/unit	24000-29000/unit	3500-4000
Microstrainer	100-300 l/min/m ²	30-40 m ²	4000-5000 \$/m ²	6400-7400 \$/m ²	6000-6500

* Capacity expressed as flow rate per meter of screen width

** Unit has 3 screws

presented in Table 33. The costs are specified in relation to effective clarification area based on a flow in the range of 5000 to 6000 l/min.

The equipment cost for the conventional clarifier includes the feedwell, drive, centre support structure, two skimmers, and walk-way, as well as the weir and baffle. Equipment costs for the solids contact clarifier include these items but instead of a feedwell it has the larger flocculation chamber with two flocculating paddles as well as a heavier mechanism to support the extra weight. The inclined plate clarifier equipment cost is for a package unit including the plates, tank, and support legs. Equipment costs for all three types also include sludge pumps with connecting piping and valves, electrical, and instrumentation. The total installed cost includes equipment installation and for the conventional and solids contact units a concrete tank.

The flotation equipment costs include the float skimmer, sediment scraper, sludge pumps, air pressure tank, flocculators, recirculation pump, drives, instrumentation, electrical, and system piping. The total installed cost includes installation of equipment and construction of a concrete tank.

The addition of chemicals to any of these processes for coagulation and/or flocculation will increase the capital costs as well as the operating costs. In all cases a chemical tank, feed pump, controls, and piping will be required; costs are based on one chemical feed system although in some cases there may be two. However, only the conventional and inclined plate clarifiers will incur the additional costs of a flocculation tank.

Chemical costs are not included in the annual operating costs. Regular cleaning of the inclined plate clarifier is included. The higher operating costs for the flotation system are due to the relative complexity of the system and consequent higher maintenance requirements and operating attention.

Chemical costs are highly variable depending on required dosages but for the hypothetical case of applying 100 mg/l of alum and 1 mg/l of polyelectrolyte the costs are approximately 1.0 to 1.5¢/1000 litres of effluent; for a flow rate of 5000 l/min the annual costs would be \$25,000 to \$40,000.

TABLE 33. SEDIMENTATION AND FLOTATION COSTS

<u>Equipment Type</u>	<u>Capacity (1/min/m² *)</u>	<u>Cost Basis Size (m²)</u>	<u>Equipment Cost (\$/m²)</u>	<u>Total Installed Cost (\$/m²)</u>	<u>Total Installed Cost with Chemical Flocculation (\$/m²)</u>	<u>Annual Operating Cost (\$)**</u>
Conventional Circular Clarifier	20-30	200-300	125-150	400-450	475-525	10000-15000
Circular Solids Contact Clarifier	20-30	200-300	200-225	500-550	525-575	15000-20000
Inclined Plate Clarifier	15-25	200-400	375-400	400-425	475-500	15000-20000
Flotation System	50-100	50-100	1200-1500	1800-2200	2000-2400	20000-30000

* m² of effective clarification area

** Not including chemicals

7.2.5 pH control

The pH of effluents from wet debarkers is often less than the desired range for corrosion protection or to meet regulatory limits. Therefore, neutralization may be required prior to discharge. If lime is used for suspended solids and/or colour removal then the pH may be increased to within the required limit as an additional benefit and separate pH control may not be required. Otherwise lime, caustic or other base may have to be applied.

Assuming the application of a liquid base such as a 50% caustic solution the approximate installed capital cost is \$10,000 to \$15,000 including storage tank, piping, metering pump, controls, electrical, and installation. At some installations, with extensive recycle, this approach may be overly sophisticated and the periodic manual addition of base to a sump may be adequate, in which case the capital cost may be nil. If solid caustic is used, or solid forms of lime such as quicklime (CaO) or hydrated lime ($\text{Ca}(\text{OH})_2$), the capital cost will be more as dissolution equipment must also be provided. The optimum method must be determined for each application.

The operating costs are due almost entirely to chemical costs and will vary considerably depending on initial and target effluent pH as well as the buffering capacity of the effluent. These costs should, in general, be in the range of 0.1¢ to 0.5¢ per 1000 litres of effluent.

7.2.6 Biological treatment

Although there are presently few biological treatment systems on wet debarker effluents specifically, future regulations may require such treatment for BOD_5 reduction and/or toxicity removal. The two most common and successful biological treatment methods on wood product effluents are the aerated lagoon and the conventional activated sludge; other methods such as the trickling filter, rotating biological contactor, and variations of the activated sludge may be considered in some cases but generally are not fully proven or are too costly. If the land is available and at a reasonable cost the aerated lagoon is almost always the appropriate choice because not only is the capital cost less but the aerated lagoon is inherently more stable, requires less maintenance, and less operating attention.

Table 34 presents approximate installed capital and operating costs for the aerated lagoon and activated sludge processes.

TABLE 34. BIOLOGICAL TREATMENT COSTS

<u>Treatment Method</u>	<u>Installed Capital Cost (\$/kg BOD₅ applied/day)</u>	<u>Annual Operating Costs (\$)</u>
Aerated Lagoon	100-150	50,000 - 75,000
Activated Sludge	200-300	100,000 - 150,000

Land costs are assumed to be \$20,000 per hectare. Installed capital costs are quoted in dollars per kilogram of BOD₅ applied per day for inputs in the 4000 to 8000 kg/day and flows in the 5000 to 6000 l/min range. Activated sludge capital costs are approximately twice those for an aerated lagoon due primarily to more structures, and equipment such as a secondary clarifier and sludge handling; obviously the capital cost can vary considerably depending on land costs. Annual operating costs are also about twice as much due to higher nutrient requirements, more operator attention, maintenance, and sludge handling.

7.2.7 Colour removal

Unlike toxicity, the colour in wood product effluents is not reduced by biological treatment, as previously discussed, and therefore separate facilities must be provided for this purpose. Current and potential full scale colour removal treatment methods are discussed in section 6.2.7 (Colour reduction). Because of the few full scale colour removal installations, the continual advancements in colour removal technology, and the fact that effluent colour regulations may not be invoked for some years, and then conceivably only at selected locations, cost estimating is not particularly relevant at this time. However, order of magnitude costs for colour removal treatment for a woodroom effluent having a flow in the area of 5000 l/min could involve a capital expenditure in the order of \$750,000 with annual operating costs in the range of \$100,000 to \$200,000.

Colour removal methods such as alum or lime coagulation-precipitation may in some cases be combined with suspended solids removal and therefore reduce the overall treatment system cost.

7.2.8 Sludge handling

The options for sludge dewatering and disposal are discussed in Section 6.2.7.

At mills that press and use the bark for hog fuel, bark fines recovered by screening are usually similarly treated. The main cost involved here is the conveying of the bark fines to the press. The installed capital cost, of course, will depend on the distance from screen to press but the approximate unit cost for conveying is \$800 to \$1200 per metre of conveyor length for a belt-type conveyor and \$1300 to \$1700 per metre for a drag chain-type conveyor.

Mills that use clarifiers for bark fines recovery generally dewater the recovered sludge by vacuum filtration and then press it with the bark and use it as hog fuel. Centrifuges are also used for this purpose and produce about the same sludge consistency of 20 to 25% O.D. solids. The belt press, which is common in Europe but relatively new to North America, is gaining in popularity as it has the potential to produce a drier sludge cake (over 30% consistency) for about the same capital and operating costs. Approximate installed capital and operating costs for dewatering equipment are presented in Table 35.

TABLE 35. SLUDGE DEWATERING COSTS

<u>Dewatering Equipment</u>	<u>Installed Capital Cost (\$)</u>	<u>Annual Operating Costs (\$)</u>
Rotary Vacuum Filter	100,000 - 125,000	20,000 - 25,000
Centrifuge	150,000 - 200,000	25,000 - 30,000
Belt Press	100,000 - 125,000	20,000 - 25,000

These costs are based on dewatering a 2% sludge at a rate of 0.45 tonne O.D. solids per hour (this is approximately equivalent to the removal of 1500 mg/l of suspended solids from 5000 l/min of effluent). These costs include associated equipment such as filtrate receiver, vacuum pump, filtrate pump, and connecting piping in the case of the vacuum filter, and motors, drives and instrumentation for all three.

Mills that landfill their bark will invariably landfill recovered bark fines and sludge also; settling basin sludge is usually landfilled in any case. Costs can be broken down into loading, hauling, and landfilling. Costs for these operations are presented in Table 36.

TABLE 36. SLUDGE DISPOSAL COSTS

<u>Operation</u>	<u>Cost (\$/m³)</u>
Loading	1.50-2.00
Hauling	2.00-3.00
Landfilling	1.50-2.00

The loading costs are for loading trucks with a front-end loader. Hauling costs will be directly proportional to the haulage distance and/or time, and for this case a round trip was assumed to take one to one and a half hours. Landfilling costs include the use of a bulldozer for landfill preparation; landfill preparation costs will depend on the terrain, soil characteristics, and techniques as required by local regulations. The total costs, therefore, for disposal of sludge to landfill should be in the area of \$5 to \$7 per m³.

7.3 Overall Cost Considerations

This section presents estimates for converting from wet to dry drum and hydraulic to mechanical ring debarking. Costs are summarized in Table 37 and are based on information presented in previous sections, particularly Section 3. Because some of these effects are site specific, generalization involves some basic assumptions which are discussed below.

Operating cost. This has been discussed extensively in Section 7.1 and consists of power, operating labour and maintenance. In converting from wet to dry drum there is essentially no difference in operating cost. In converting from hydraulic to mechanical ring debarking there is an estimated saving of \$0.24/m³ (\$0.68/cunit).

Bark pressing and effluent screening. The cost of bark pressing and simple screening of the effluent averaged \$0.1/m³ (\$0.28/cunit) based on an evaluation at two sawmill installations. This cost includes power and maintenance; separate operating labour was not required. This cost item was not evaluated at wet drum installations but is expected to be similar.

Depreciation due to conversion. Based on mill experiences and assuming an annual depreciation charge of 10%, conversion of existing drums from wet to dry operation results in a cost of \$0.05 to \$0.07/m³ (\$0.14 to

TABLE 37. ESTIMATES OF THE ECONOMIC EFFECTS OF
CONVERSION FROM WET TO DRY DEBARKING

<u>Item</u>	<u>Wet to Dry Drum</u>		<u>Hydraulic to Mechanical Ring</u>	
	Savings (\$/m ³)	Additional Cost (\$/m ³)	Savings (\$/m ³)	Additional Cost (\$/m ³)
Operating Cost	-	-	0.24	-
Bark Pressing & Effluent Screening	0.1	-	0.1	-
Depreciation	-	0.1	-	0.1
Production Rate	-	0.1	-	-
Bark Residual	-	0.1	-	0.05
Energy Recovery	0.1	-	-	-
Wood Loss	-	-	-	0.03
Pretreatment	-	0.06	-	-
Maintenance Due to Grit	-	0.06	-	0.06
Effluent Treatment	0.25	-	0.25	-
Total	0.45	0.42	0.59	0.24

\$0.20/cunit). At one installation where an old system was completely replaced, depreciation charges were greater ($\$0.35/\text{m}^3$ or $\$1.00/\text{cunit}$). In the case of conversion from hydraulic to mechanical debarking, the cost is $\$0.05$ to $\$0.11/\text{m}^3$ ($\$0.14$ to $\$0.31/\text{cunit}$). Thus, an average depreciation cost for either conversion is approximately $\$0.1/\text{m}^3$ ($\$0.28/\text{cunit}$).

Cost due to lower production rates. This has been identified to be a problem only with drum debarking. For mills that had not appreciably altered drum capacity in converting from wet to dry, decreases in debarking rates ranged from 0 to 30%. There is, of course, some tradeoff with residual bark. However, assuming presteaming is provided for frozen wood in the dry system, the most probable values would be a 10% production drop equivalent to an additional cost of $\$0.1/\text{m}^3$ ($\$0.28/\text{cunit}$).

Cost due to higher bark residuals. Based on mill experiences presented in Section 3, and the product quality assessment in Section 4, and assuming provision of pretreatment for frozen wood and a nominal decrease in production rates, about a 1% increase in residual bark can be expected with dry compared to wet drum debarking.

Based on mill experiences with concurrent hydraulic and mechanical debarking and the product quality assessment, 0.5% increase in residual bark can be expected at pulp mill installations. At sawmill installations debarking better quality logs, differences should be minimal.

Estimates of the economic consequences of residual bark as presented in Section 2.1 range from an additional cost of $\$0.11$ to $\$0.94/\text{m}^3$ ($\$0.31$ to $\$2.66/\text{cunit}$) for a bleached kraft mill that is pulping and recovery limited. Consequences for other types of pulp production have not been estimated. The most rational value is that estimated by Thomas and Howse (1975) of $\$0.11/\text{m}^3$ ($\$0.31/\text{cunit}$). Thus, assuming off-specification pulp is not produced and a kraft pulp mill application, the additional cost for dry drum debarking is about $\$0.1/\text{m}^3$ ($\$0.28/\text{cunit}$) and for mechanical debarking about $\$0.05/\text{m}^3$ ($\$0.14/\text{cunit}$).

Energy recovery. For mills recovering energy from hog fuel, the conversion to dry debarking may result in greater hog fuel utilization as well as drier hog fuel. While increased utilization has been noted by a

few installations where bark pressing had been a bottleneck, drier hog fuel is the predominant benefit. Based on the discussion in Section 4.7, the moisture content of unpressed hog fuel from dry debarking compared to pressed hog fuel from wet debarking would be significantly lower only for dry stored logs. This would only apply to drum installations since hydraulic debarking installations in general practice wet storage. The net savings for dry drum debarking assuming 45% compared to 50% moisture and an equivalent oil cost of \$0.07/l (\$0.25/US gal) would be about $\$0.1/\text{m}^3$ (\$0.28/cunit).

Cost due to additional wood loss. As discussed in Section 4.4 values of wood loss quoted in the literature vary appreciably. Based on values obtained in this study, it appears that wet and dry drum debarking have similar wood loss (4 to 5%). Mechanical debarking appears to have about 1% higher wood loss compared to hydraulic debarking (2.5% vs. 1.5%). While wood loss represents a loss in wood value, it also contributes to the value of the hog fuel assuming the mill recovers energy from this source. For a wood cost of $\$12/\text{m}^3$ (\$35/cunit), a 1% wood loss represents an additional cost of $\$0.12/\text{m}^3$ (\$0.35/cunit). On the other hand, a 1% wood loss is equivalent to about a 5% increase in the quantity of hog fuel or an energy savings of $\$0.09/\text{m}^3$ (\$0.25/cunit). Thus, the net cost for an additional 1% wood loss is $\$0.03/\text{m}^3$ (\$0.1/cunit).

Debarking pretreatment cost. Based on a review of several dry drum debarking installations, prestaming requirements for frozen wood average 1100 kg steam/hr/drum (2500 lb steam/hr/drum). Based on a steam cost of \$4.4/tonne (\$2/1000 lb) and a typical drum capacity of $40 \text{ m}^3/\text{hr}$ (14 cunits/hr) this is equivalent to a cost of $\$0.12/\text{m}^3$ during the winter months or $\$0.06/\text{m}^3$ (\$0.17/cunit) over the entire year.

Pretreatment would not be required for the mechanical debarking installations since these are usually employed in mild climates.

Maintenance due to grit. The greater quantity of grit carried over into the hog fuel and chips with dry debarking results in increased wear in the bark handling and shredding system, the chipping system and increased frequency of boiler cleaning. The additional maintenance for one mill was estimated to be $\$0.06/\text{m}^3$ (\$0.17/cunit).

Effluent treatment cost. It is assumed that preliminary removal of bark fines by screening already exists and that the mill requires a separate treatment facility for only debarker effluent. This facility would include effluent neutralization facilities, a minimum of 90% suspended solids removal by chemically assisted sedimentation and a minimum of 80% BOD₅ removal by biological treatment. It would also be capable of rendering the effluent non-toxic. Because of uncertainties in the status of colour removal, facilities for such treatment have not been included.

Although the effluent flow rate may be less for a wet drum compared to a hydraulic debarker, the suspended solids and BOD₅ concentrations will be higher resulting in similar capital and operating costs for both types of effluent.

Capital costs for effluent treatment are estimated to range between \$0.08 and \$0.15/m³ (\$0.23 and \$0.42/cunit) of wood processed assuming annual depreciation charges at 10%. Operating costs are estimated to be \$0.10 to \$0.20/m³ (\$0.28 to \$0.56/cunit). Therefore, the total cost for an effluent treatment system based on the best practicable treatment technology currently available is about \$0.25/m³ (\$0.71/cunit).

This comparison indicates that the conversion from wet to dry drum debarking has essentially no net economic consequence, but converting from hydraulic to mechanical ring debarking produces a net saving of \$0.35/m³ (\$1/cunit) of wood processed.

ACKNOWLEDGEMENTS

Many people contributed to this study including officials for forestry companies, mills, equipment suppliers, and government. Without their able assistance this project could not have been successfully completed. Their contributions are gratefully acknowledged.

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NOMENCLATURE

ADMTPD	air dry metric tons per day
ADTPD	air dry short tons per day
bf	board feet
BOD	biochemical oxygen demand
Btu	British thermal unit
C.I.	confidence interval
cm	centimetres
cunit	100 cubic feet of solid wood
dia	diameter
ft	feet
gal	gallon
hr	hour
hp	horsepower
in	inches
kcal	kilocalories
kg	kilograms
kgg	one thousand kilograms
kW	kilowatts
kWh	kilowatt hours
kPa	kilopascals
l	litre
l/min	litres per minute
lb	pounds
m	metres
m ²	square metres
m ³	cubic metres
M	thousand
MM	million
Mg	milligrams
ml	millilitres
O.D.	oven dry
pH	inverse of the logarithm of hydrogen ion concentration

psi	pounds per square inch
ton	short tons
tonne	metric tons
TSS	total suspended solids
vs	versus
US gpm	United States gallons per minute
wt	weight
%	percent
°C	degrees Celsius (centigrade)
<	less than
>	greater than

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APPENDIX 1

Power Consumption for Wet and Dry Debarking

POWER CONSUMPTION FOR WET DRUM DEBARKERS

Mill	Wood Processed			Type of Debarker & Year Installed	Power Consumption			
	Species	Dia (cm)	Wood Storage	m ³ /hr	Debarker ¹		Associated Equipment ²	
					kW	kWh/m ³	kW	kWh/m ³
1WD	Pine, Spruce, Fir	13-46	Dry	108	767	7.1	378	3.5
							1145	10.6
2WD	Hardwood mix	10-61	Dry	85	436	5.1	43	0.5
							479	5.6
3WD	Poplar, Maple, Birch	10-66	Dry	75.6	648	8.7	56	0.7
							704	9.4
4WD	Spruce, Fir	18 avg.	Wet & Dry	96.3	392	4.1	94	1.0
							486	5.1
Average				91.2			704	7.7

¹ Includes drum drives, pumps, in and out feed
² Includes flumes, press, screening

POWER CONSUMPTION FOR DRY DRUM DEBARKERS

Mill	Wood Processed			Type of Debarker & Year Installed	Power Consumption				
	Species	Dia (cm)	Storage	m ³ /hr	Debarker ¹		Associated Equipment ²		Total
					kW	kWh/m ³	kW	kWh/m ³	
100	Hemlock, Spruce, Fir	20 avg.	Dry	70.8	494	7.0	231	3.2	10.2
200	Hemlock Spruce Alder	25 avg.	Dry	20.7	126	6.1	-	-	6.1
300	Poplar, Maple, Birch	10-66	Dry	49.3	539	10.9	-	-	10.9
500			Dry	143	609	4.3	-	-	4.3
Average				71.0					7.9

¹ Includes drum drives, in and out feed

² Includes flumes and screening

POWER CONSUMPTION FOR HYDRAULIC DEBARKERS

Mill	Wood Processed			Type of Debarker & Year Installed	Debarker ¹		Associated Equipment ²		Total
	Species	Dia (cm)	Wood Storage m ³ /hr		kW	kWh/m ³	kW	kWh/m ³	
1H	Hemlock, Balsam, Cedar, Spruce	76-152	Wet 93.5	Simons Wig-Wag (183 cm) 1953	1430	15.3	120	1.3	1550 16.6
2H	Fir, Hemlock, Balsam	36-122	Wet 212	Hanse1 Wig-Wag (152 cm) 1961	1400	6.6	110	9.5	1510 7.1
3H	Cedar	15-152	Wet 139	Hanse1 Wig-Wag (183 cm) 1962	660	4.8	-	-	660 4.8
4H	Cedar	15-183	Wet 37.7	Bellingham 1958	330	8.8	-	-	330 8.8
5H	Hemlock, Spruce, Balsam	10-152	25% Wet 89.2 75% Dry	Bellingham 1966	690	7.7	80	0.9	770 8.6
6H	Cedar, Fir Spruce, Hemlock, Balsam	61-122	Wet 63.7	Bellingham	430	6.7	-	-	430 6.7
7H	Hemlock, Balsam	-	Wet 133	-	540	4.1	-	-	540 4.1
Average			110			7.7		0.9	827 8.1

¹ Includes drives, pumps, in and out feed

2 Includes press and screening

POWER CONSUMPTION FOR MECHANICAL DEBARKERS

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<u>Mill</u>	<u>Wood Processed</u>			<u>Type of Debarker & Year Installed</u>	<u>Power Consumption¹</u>	
	<u>Species</u>	<u>Dia (cm)</u>	<u>Storage</u>		<u>kW</u>	<u>kWh/m³</u>
1M	Cedar, Hemba1, Spruce	10-122	Wet	Nicholson A-1 (127 cm) 1975	140	1.5
2M	Hemlock, Balsam	10-61	25% Wet 75% Dry	Nicholson (66 cm) 1965	60	1.3
3M	Hemlock, Balsam	10-61	Wet	Brunette (69 cm) 1965	50	0.8
4M	Hemlock, Cedar		Wet	Nicholson (152 cm) 1975	120	1.1
5M	Hemlock, Fir	15-30	Wet	Cambio (66 cm) 1975	73	1.1
6M System A	Hemlock		Wet	Nicholson (152 cm) 1973	176	1.3
6M System B	Hemlock		Wet	Brunette (89 cm) 1975	64	1.5
Average					97.6	1.2

¹ Includes ring drive, in and out feed

APPENDIX 2

Hog Fuel Energy Potential Compared to Energy Consumption

Energy Generated from Hog Fuel

- Basis
- 50% moisture content (wet basis),
 - 4770 kcal/kg dry, 2380 kcal/kg wet,
 - 160 kg/m³ wood processed,
 - 65% boiler efficiency,
 - 907 kcal/kWh.

Energy Generated = 268 kWh/m³ wood processed.

Energy Consumption in Wood Preparation

Total woodroom and woodyard = 13 to 18 kWh/m³ wood processed (according to Scherian's (1975) data).

Debarking = 1.2 to 8.1 kWh/m³ wood processed (according to averages in Section 2.4).

APPENDIX 3

Chip Residual Bark Content and Wood Loss
for Mills Sampled

CHIP RESIDUAL BARK CONTENT AND WOOD LOSS FOR MILLS SAMPLED

175

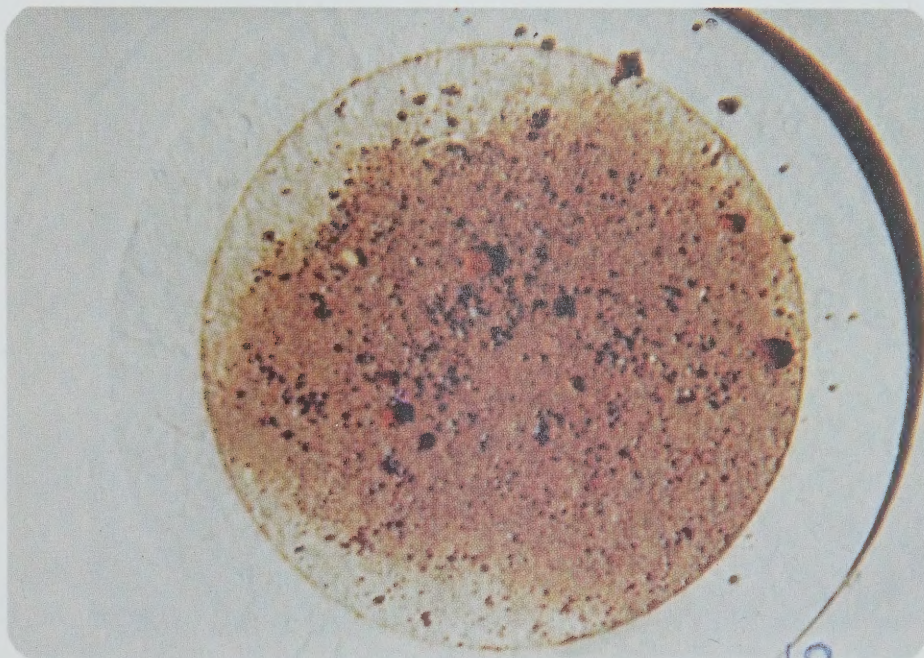
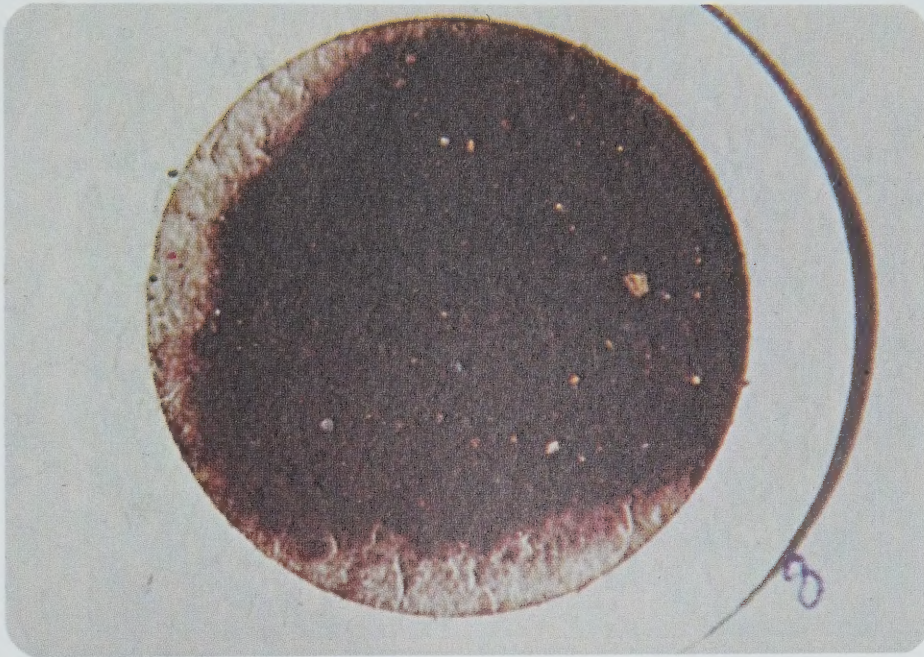
MILL LOCATION & CODE	TYPE OF DEBARKING AND CHIPPING	PRODUCTION PER DEBARKER (m ³ /hr)	DATE DEBARKED & AMBIENT TEMP.	WOOD DATA		RESIDUAL BARK CONTENT FOR ALL FRACTIONS (% BY WT.)		WOOD LOSS (% BY WT.)				
				SPECIES	AVG. SIZE (cm)	STORAGE & TRANSPORT	MEAN ± 95% C.I.	RANGE	MEAN ± 95% C.I.	RANGE		
G	WESTERN SAWMILL	210	Feb. 1977 9 to 11°C	HEMLOCK BALSAM	61	WET	0.3	0.2	<0.1-0.4	1.1	1.1	0.2-2.5
D-1	WESTERN SULFITE PULP MILL	77.0	Feb. 1977 8 to 12°C	HEMLOCK BALSAM	36	WET	0.4	0.5	<0.1-1.1	1.4	0.4	1.0-1.8
A-SM	EASTERN SAWMILL	37.7	Jan. 1977 -6 to -20°C	JACK PINE SPRUCE	13	DRY	1.3	0.4	0.9-1.8	3.3	4.7	0.1-7.3
A-LG	EASTERN SAWMILL	31.7	Jan. 1977 -6 to -20°C	JACK PINE SPRUCE	23	DRY + HOT POND	0.9	1.6	0.4-1.6	1.9	1.6	0.9-4.0
B	WESTERN SAWMILL	64.6	Feb. 1977 7. to 11°C	HEMLOCK	48	WET	0.2	0.1	0.2-0.3	2.0	1.6	0.7-3.9
D-2	WESTERN SULFITE PULP MILL	37.7	Mar-Apr. 1977 6 to 16°C	HEMLOCK BALSAM	25	WET	1.8	1.5	0.4-3.4	2.6	2.9	1.2-6.6

MILL CODE	LOCATION & TYPE OF MILL	TYPE OF DEBARKING AND CHIPPING	PRODUCTION PER DEBARKER (m ³ /hr)	DATE DEBARKED & AMBIENT TEMP.	WOOD DATA		RESIDUAL BARK CONTENT FOR ALL FRACTIONS (% BY WT)		WOOD LOSS (% BY WT)				
					SPECIES	AVG. SIZE (cm)	STORAGE & TRANSPORT	MEAN ± 95% C.I.	RANGE	MEAN ± 95% C.I.	RANGE		
F	WESTERN BLEACHED KRAFT PULP MILL	HORTON WET DRUMS WHOLE LOG CHIPPING	36.2	Feb. 1977 -6 to 11°C	PINE SPRUCE BALSAM	23	DRY	0.6	0.3	0.3-0.7	3.9	1.5	1.9-5.0
H	EASTERN NEWSPRINT MILL	CIR WET DRUMS WHOLE LOG CHIPPING	42.5	Mar. 1977	SPRUCE BALSAM	15	DRY	0.7	0.6	0.3-1.1	6.6	4.0	3.6-9.1
I	EASTERN BLEACHED KRAFT PULP MILL	CIR WET DRUMS WHOLE LOG CHIPPING	36.8	Mar. 1977	HARDWOOD MIX	20	DRY	0.9	0.5	0.5-1.5	4.3	5.7	1.3-12.2
E	EASTERN NEWSPRINT MILL	KMW DRY DRUMS WHOLE LOG CHIPPING	34.0	Feb-Mar. 1977 -13 to 0°C	SPRUCE BALSAM	18	DRY	1.3	1.3	0.3-3.0	6.3	7.7	0.8-13.5
C	EASTERN BLEACHED KRAFT PULP MILL	HOOPER DRY DRUMS WHOLE LOG CHIPPING	41.1	Feb. 1977 -4°C	HARDWOOD MIX	25	DRY	4.2	1.7	3.0-5.5	3.2	3.5	1.4-5.3

APPENDIX 4

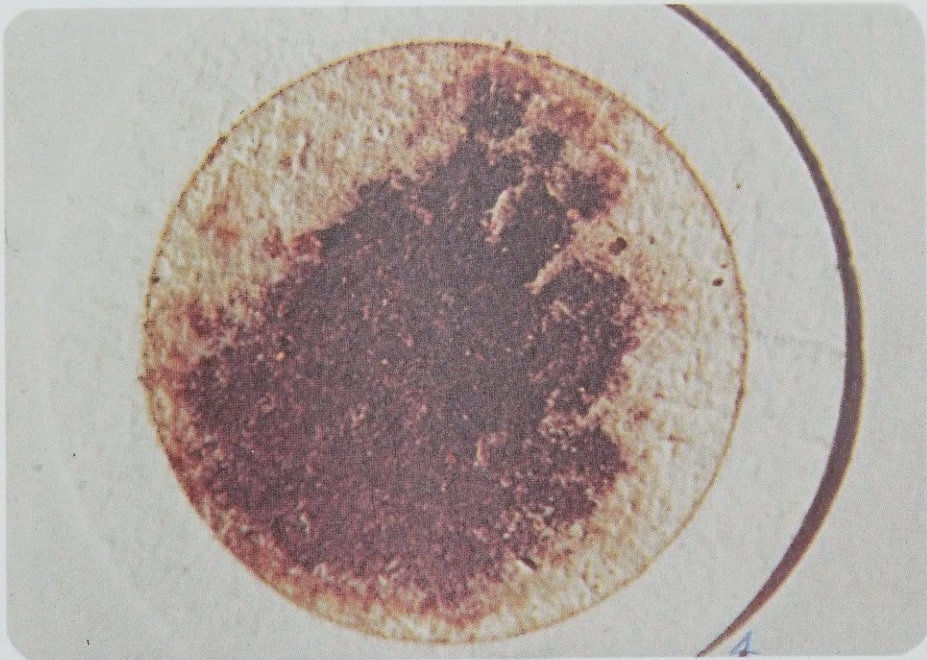
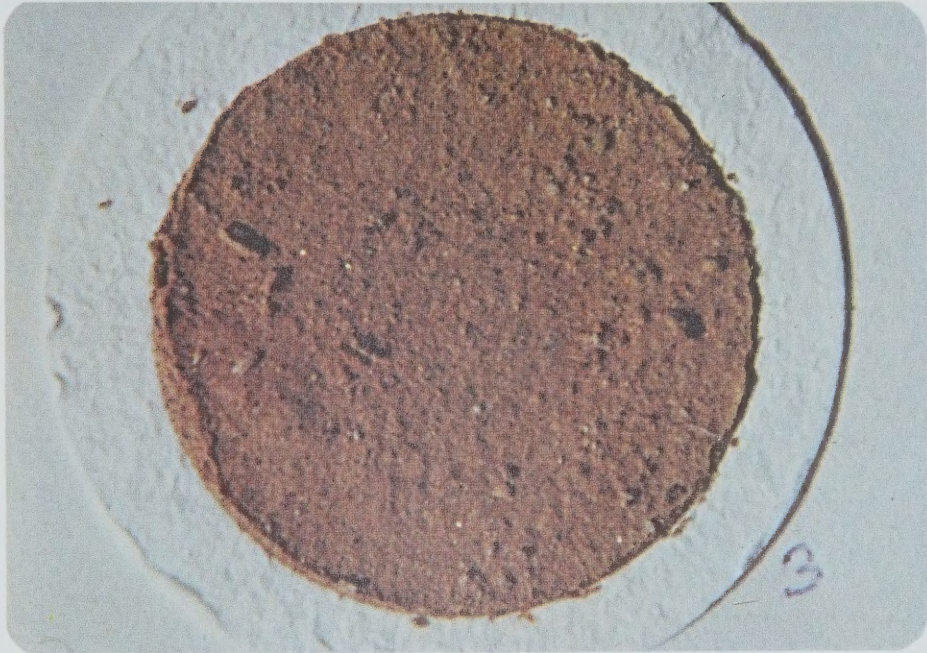
Photographs of Bark Particulate

Particulate content in bark from Mill D. Same source of water stored logs mechanically debarked (10) and hydraulically debarked (8).

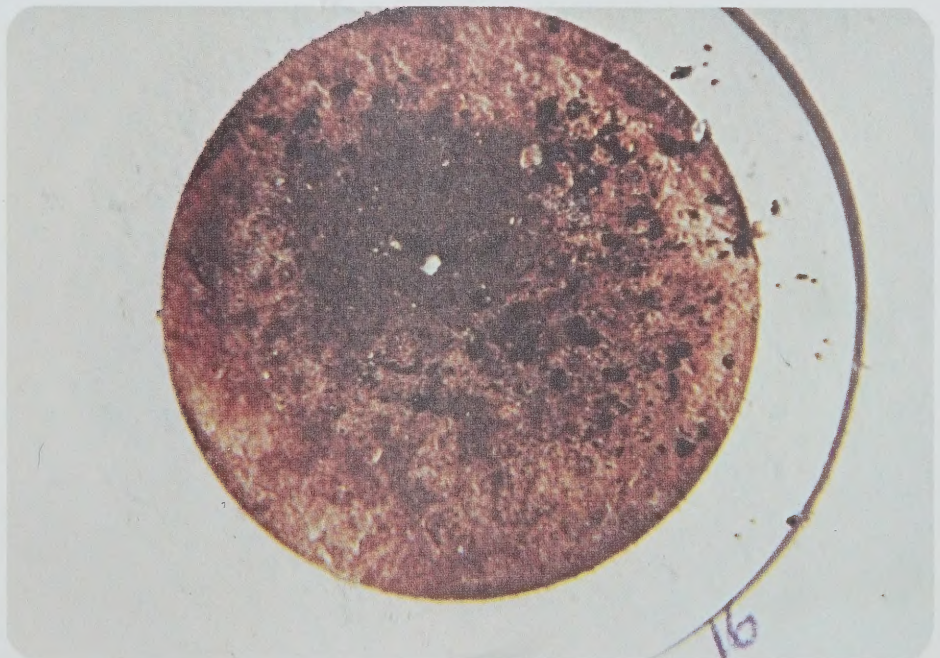
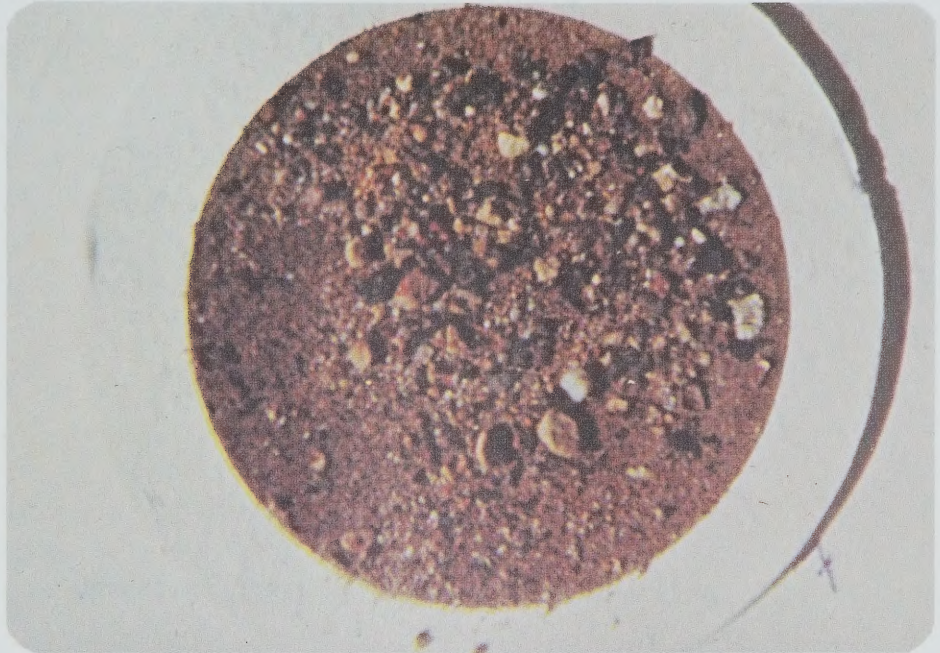


Note: Particulate is material that stands out on filter. Bark ash is much finer and is imbedded in the filter.

Particulate content in bark from Mill A with (4) and without (3) log pond.
Same source of dry stored logs mechanically debarked.



Comparison of particulate in bark from Mill C with dry drum debarking (7) and Mill I with wet drum debarking (16). Both mills debarking 1and stored hardwood logs.



APPENDIX 5

Operating Costs for Wet and Dry Debarking

OPERATING COSTS FOR DRUM DEBARKERS

Mill	Type of Drum	Wood Processed (m ³ /hr)	Debarking Costs, \$/m ³			Total
			Power	Operating Labour	Maintenance Labour & Materials	
5WD	Wet	143	0.10	0.83	0.17	1.10
4DD	Dry	123	0.14	0.49	0.18	0.81 ¹
2WD	Wet	85	0.05	0.71	0.71	1.47
3WD & DD	Wet & Dry	125	0.02	0.28	0.12	0.42 ¹
Average		119	0.08	0.60	0.27	0.95

¹ Estimated from total woodroom operating cost by taking maintenance at 10%, operating labour and power at 50%.

OPERATING COSTS FOR HYDRAULIC DEBARKERS

Mill & Year of Cost Base	Wood Processed (m ³ /hr)	Debarking Costs, \$/m ³				Total ¹
		Energy	Operating Labour	Maintenance Labour & Materials	Pressing & Screening	
1H 1975/76	93.5	0.27	0.16	0.16	0.13	0.60
2H 1975/76	212	0.10	0.10	-	0.21	0.41
3H 1976	139	0.11	0.07	0.14	-	0.32
4H 1976	37.7	0.14	0.26	0.26	-	0.66
Average	121	0.16	0.15	0.20	0.10	0.51

¹ Does not include pressing & screening cost

OPERATING COSTS FOR MECHANICAL DEBARKERS

<u>Mill & Year of Cost Base</u>	<u>Wood Processed (m³/hr)</u>	<u>Debarking Costs, \$/m³</u>		
		<u>Energy</u>	<u>Operating Labour</u>	<u>Maintenance Labour & Materials</u> <u>Total</u>
1M 1976	93.5	0.02	0.16	0.19 0.37
5M 1976	68.0	0.01	0.15	0.21 0.37
6M - System A 1976	130	0.04	0.07	0.01 0.12
6M - System B 1976	43.3	0.04	0.21	0.03 0.28
Average	83.7	0.02	0.14	0.11 0.27

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